"It is not the critic who counts: not the man who points out how the strong man stumbles or where the doer of deeds could have done better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood, who strives valiantly, who errs and comes up short again and again, because there is no effort without error or shortcoming, but who knows the great enthusiasms, the great devotions, who spends himself for a worthy cause; who, at the best, knows, in the end, the triumph of high achievement, and who, at the worst, if he fails, at least he fails while daring greatly, so that his place shall never be with those cold and timid souls who knew neither victory nor defeat."

—Theodore Roosevelt

University of Alberta

Projecting the Future Burden of Diabetes in Alberta (2006-2035)

by

Robin Sai Bung Lau ©

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in partial fulfillment of the requirements for the degree of

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Dedication

I dedicate this thesis in memory of my grandfather, Ka Sing Li, who passed away on June 5, 2008. He believed that education was important for producing opportunities, for self-improvement, and for the greater good of society.

Abstract

Objective: To assist in policy decision making regarding diabetes prevention and treatment strategies, an economic forecasting model was developed that will help integrate observed epidemiologic trends and clinical research.

Methods: The forecasting model is based on epidemiological data (incidence, prevalence, and mortality rates) obtained from Alberta Diabetes Surveillance System (ADSS) and population projections, from Alberta Health and Wellness. Using these data, we created a life table model which projects the populations' yearly progression into diabetic states for 5-year age bands (starting with the 1–4 years of age band) for males and females. Patterns of changing incidence and mortality were extracted from the ADSS data using regression and applied to the model.

Results: If current trends continue for the next 10 years, overall prevalence will double between 2005 and 2035, from approximately 4% to 11.5%, and total costs will increase by 337%, with the highest percentage increase found in cardiovascular and eye care.

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List of Abbreviations

ADA	American Diabetes Association
ADSS	Alberta Diabetes Surveillance System
CDA	Canadian Diabetes Association
CORE	Centre for Outcomes Research
CPI	consumer price index
CV	cardiovascular
DCCT	Diabetes Control and Complications Trial
DM	Diabetes mellitus
DPP	Diabetes Prevention Program
FFA	free fatty acids
HbA1c	hemoglobin A1c
HMO	health maintenance organization
HRQL	health related quality of life
HUI3	Health utilities index Mark 3
IGT	impaired glucose tolerance
INR	Indian Rupees
LSM	lifestyle modification
NDSS	National Diabetes Surveillance System
NHANES	National Health and Nutrition Examination Survey
NHIS	National Health Interview Survey
NNT	number needed to treat
ODEM	Ontario Diabetes Economic Model
QALY	quality adjusted life year
RCT	randomized control trial

UKPDS	United Kingdom Prospective Diabetes Study
US	United States of America
WESDR	Wisconsin Epidemiologic Study of Diabetic Retinopathy
WHO	World Health Organization

1.0 Introduction

Diabetes was found to be the seventh leading cause of death in Canada in 1997 (Statistics Canada, 2005) and it is associated with higher utilization of general practitioners, specialist services, emergency services, and hospitalizations (Johnson et al., 2007a). To pay for the cost of increased utilization of health services, the already limited resources may need to be reallocated among diabetes and other important health care and nonhealth care services. Research has shown that costs associated with diabetes and its related comorbidities are increasing and this disease is estimated to cost the Canadian health care system $13.2 billion per year (Canadian Diabetes Association, 2006). In Alberta, incidence and prevalence rates for diabetes were found to increase from 1995 to 2005, while mortality rates declined (Johnson and Vermeulen, 2007; Canadian Diabetes Association, 2006; Lipscombe, 2007; Chodick et al., 2005; Rubin et al., 1994; Williams et al., 2002). Globally, economic forecasting models have shown that the prevalence of diabetes is steadily rising, and it is not a localized chronic condition (King et al., 1998; Wild et al., 2004; Mainous et al., 2007; Boyle et al., 2001; Ohinmaa et al., 2004).

Research has shown that pharmacotherapy and lifestyle changes—improved diet and physical activity—are able to prevent or delay the onset of diabetes (Pan et al., 1997; The Diabetes Prevention Program, 2002; Lindstrom et al., 2003; Ramachandran et al., 2006). Cost analysis studies on lifestyle intervention and drug therapy have been shown to be cost effective (Ramachandran et al., 2007; Herman et al., 2005; The Diabetes Prevention Program Research Group, 2002). Clinical trials of various interventions have demonstrated the efficacy of the interventions but there is an absence of research investigating the effectiveness and costs of these interventions for the general population. The lack of research and knowledge translation has lead to gaps in policy and noncohesive efforts to address complications of this disease and the impact of diabetes on current and future health. The urgency and importance of treating and preventing diabetes needs to be communicated to policy makers and the public, however, in order to do so there is a need for relevant research and economic models to study the current and future burden of diabetes; these models will bridge the gap between research and policy, helping to simplify complicated problems into a form that can be easily managed. The lack of

knowledge transfer from research into policy has resulted in maintaining the status quo with regard to diabetes management and prevention.

An economic model is a simplified theoretical representation of a specific aspect of the real world; it reduces information to its important components (Stokey and Zeckhauser, 1978). Models provide information by either being (1) descriptive—describing how a specific aspect of the world works, or (2) prescriptive—describing courses of action and outcomes in the real world that can be categorized as deterministic, outcome assumed to be certain, or probabilistic, outcome assumed to be uncertain (Stokey and Zeckhauser, 1978). Models inform policy making by providing insight as to how things are related and how they affect each other. Models need to be frequently updated with new information to improve our understanding of how the real world functions and operates; otherwise, the status quo remains persistent and unquestioned (Stokey and Zeckhauser, 1978) leading to long term problems and complications.

In the past, researchers have used Markov models (Brandle and Herman, 2004; Palmer et al., 2004) and life table models (Ohinmaa et al., 2004) to project future outcomes in diabetes. The strength of a model is based on the quality of the assumptions incorporated. In Markov models, the assumptions are based on transition probabilities which determine the rate of transitioning of a base cohort from one state to the next. The model will then be as robust as the quality of the transition probabilities and the studies that produced them. With a life table approach, the model follows a base population, that is, a cohort (e.g., 100,000, whole population) and applies population probabilities that state the rate of transition from one state to the next. Usually, these population transition probabilities are based on population-wide epidemiological data.

Previous diabetes projection models such as the United Kingdom Prospective Diabetes Study (UKPDS) (Clarke et al., 2004), the Ontario Diabetes Economic Model (ODEM) (O'Reilly et al., 2006), and the Centre for Outcomes Research (CORE) Diabetes Model (Palmer et al., 2004) have been used to predict the timing and occurrence of diabetes, its related comorbidities, and its associated costs (O'Reilly et al., 2006; Brandle and Herman, 2004). The UKPDS was a large scale, randomized control trial between the years of 1977 and 1991; it included 5102 patients aged 25 to 65 years with newly diagnosed type 2 diabetes. From the trial results, risk factors from the clinical

trials, that is, hemoglobin A1c (HbA1c), systolic blood pressure, and HDL cholesterol, were incorporated into the UKPDS model (Clarke et al, 2004). The resulting product is a probabilistic discrete time illness/death model which follows patients with given health states up to their deaths. The Ontario Diabetes Economic Model (ODEM), based on the UKPDS model, faced problems of applicability in a different setting (O'Reilly et al., 2006). Incidence, prevalence, baseline demographics, diabetes risk factors, mortality, and costs of treatment and management were different between countries (O'Reilly et al., 2006). The UKPDS model was adapted to the Ontario setting through a merger of various data bases containing information on baseline risk factors, complication rates, resource utilization, and costs of treating diabetes and its related complications (O'Reilly et al., 2006).

The CORE Diabetes Model combines many Markov submodels that simulate diabetes comorbidities (Brandle and Herman, 2004). The CORE Diabetes Model is an Internet based, interactive computer simulation that predicts long term health outcomes and economic consequences of diabetes (type 1 and type 2) (Brandle and Herman, 2004; Palmer et al., 2004). The CORE Diabetes Model allows for users to specify situations to be modeled using the input databases of the CORE model; it consists of (1) the cohort database that allows the user to specify patient demographics and various risk factors, (2) a clinical database that allows the user to vary the probabilities of transition to various acute or chronic patients states, (3) a treatment database that allows the user vary the effects of treatments, and (4) an economics database that allows the user to vary costs to perform cost analyses. The model is based on data from the UKPDS, the Diabetes Control and Complications Trial (DCCT), the Framingham Heart Study, and the Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR), but the user can change and vary the probabilities (Palmer et al., 2004).

Weinstein et al. (2003) stated that the quality of a model will depend on the (1) model structure, (2) data inputs, and (3) model validation. The UKPDS, the ODEM, and the CORE Diabetes Model are considered to be good quality models that are based on clinical trial data. The model assumptions that are based on trials may hold in a clinical setting and in a specific population of individuals that possess the specific risk factors stated. However, when these models are applied to a general population setting, they may

not accurately reflect actual diabetes incidence, prevalence, mortality, and costs, resulting in outcome bias. For example, the current economic models assume that a reduction in HbA1c levels will lead to a reduction in cardiovascular risk, however, these results were not proven in the UKPDS randomized control trial, when HbA1c was actively reduced (UK Prospective Diabetes Study (UKPDS) Group, 1998); the association between hemoglobin A1c and cardiovascular risk has been observed only in epidemiological studies (Stratton et al., 2000). The UKPDS, the ODEM, and the CORE Diabetes Model are important economic models and they provide insight on the timing and occurrence of diabetes complications. There is a need, however, for models that forecast diabetes incidence, prevalence, mortality, and costs at a population level and that aid decision makers to implement a unified policy to address all major risk factors associated with diabetes.

This study lays the groundwork for an economic forecasting model that will help integrate clinical research to inform policy makers. The work here is based on a previous economic model created by Ohinmaa et al. (2004). The economic forecasting model is based on epidemiological data (incidence, prevalence, and mortality rates) and population projections obtained from the Alberta Diabetes Surveillance System (ADSS) and Alberta Health and Wellness, respectively. From these data, a life table model was created which models the populations' yearly progression into diabetic states for 5 year age bands (starting with the 1–4 age group) for both genders from 2006 until 2035. Patterns of changing incidence and mortality were extracted from the ADSS data (1995–2005) using regression and applied to the model. The observed changes in incidence and mortality (1995–2005) were assumed to continue. The model forecasts prevalence and costs of diabetes in Alberta from 2006 to 2035 and the cost of diabetes using 1996 Saskatchewan cost data adjusted to 2005 Canadian dollars using the consumer price index. This model sheds light on the magnitude of the future diabetes epidemic in Alberta. Clinical research such as lifestyle intervention, population level intervention, and pharmacotherapy intervention can be applied to the projection model and the effects of these interventions on the population can be estimated. Knowing the population at risk and the relative effectiveness of intervention on incidence and mortality rates, a cost analysis can be carried out by the model.

2.0 Background and Literature Review

2.1 Diabetes mellitus

Diabetes mellitus (DM) is a chronic condition associated with increased morbidity, mortality, and economic costs and is considered to be a significant health burden. Recent estimates by the National Diabetes Surveillance System (NDSS) found that in 1999/2000, 5.1% of Canadians aged 20 and over had diagnosed diabetes; however, the prevalence of diabetes is likely grossly underestimated with 30% of people with diabetes remaining undiagnosed (Public Health Agency of Canada, 2006).

The complications associated with diabetes place an extra burden on the health care system and are seen in increased hospitalizations, increased utilization of home care, and increased medication (Statistics Canada 1999). Complications of diabetes primarily arise from hyperglycemia which affects eyes, blood vessels, kidneys, nerves, skin, and the musculoskeletal system (Williams et al., 2002); complications can be categorized into microvascular (retinopathy, nephropathy, and neuropathy) and macrovascular (cardiovascular disease, heart disease, and stroke) (Health Canada, 2002; Benedetti, 2002). Johnson et al. (2007a) found that people with diabetes are 2, 3, and 10 times more likely to visit a general practitioner, specialist, or an emergency department, respectively. People with diabetes are 2.5, 2.5, and 2 to 4 times more likely to be hospitalized for cardiovascular or kidney disease, to have heart failure, and to require coronary revascularization procedures, respectively (Johnson et al., 2007a; Graham et al., 2007; McAlister et al., 2007).

Diabetes is defined as the body's inability to produce or use insulin, resulting in the body's inability to control blood sugar levels. Insulin is produced by the islet cells of the pancreas, and is responsible for removing glucose from the bloodstream by converting it to glycogen; insulin is also responsible for the entry of glucose into muscle. Type 1 and type 2 diabetes affect 10% and 90% of the diabetic population, respectively, and 96% of total expenditures were used to provide care to individuals with type 2 diabetes (Johnson et al., 2006). Individuals with type 1 diabetes, previously known as juvenile onset diabetes, are insulin dependant and require daily injections of insulin; type 1 diabetes is typically caused by genetic and environmental factors. Type 2 diabetes, known as adult onset diabetes or noninsulin dependant diabetes mellitus, does not require

daily injections of insulin, although insulin may be used in advanced cases; type 2 diabetes is associated with lifestyle factors such as physical inactivity, obesity, and high blood pressure (Health Canada, 2002).

Studies have found a reduction of life expectancy in diabetic patients (Ruwaard et al., 2003) and a decreased quality of life (Koopmanschap, 2002; Coffey et al., 2002). The burden of diabetes on patients and the health care system is enormous and it is predicted that the incidence, prevalence, and costs associated with treating diabetes are on the rise (Boyle et al., 2001; Ohinmaa et al., 2004; Mainous et al., 2007; King et al., 1998; Wild et al., 2004).

2.2 Costs associated with diabetes mellitus

The Canadian Diabetes Association (CDA) (2006) reports that health care costs are about two to three times larger for people with diabetes than for people without diabetes, with direct costs ranging from $1000 to $15000 a year (Canadian Diabetes Association, 2006). The direct costs of diabetes were found to range from 2.5% to 15% of health care budgets (WHO, 2006). Chodick et al. (2005) found that direct costs accrued by health maintenance organizations (HMO) are rising faster for diabetes than for other illnesses; 29% and 19%, respectively. Rubin et al. (1994) found direct health care expenditures in the United States to be 3.6 times greater for people with diabetes than for people without diabetes. A large proportion of the increasing costs related to diabetes are associated with multiple complications; Williams et al. (2002) found that costs increased 100%, 200%, and 450% for microvascular, macrovascular, and both microvascular and macrovascular complications, respectively. The CDA estimates that 13.2 billion dollars a year are spent on treating diabetes and its related complications (Canadian Diabetes Association, 2006). This number is predicted to increase to 15.6 billion a year by 2010 and to 19.2 billion a year by 2020 (Canadian Diabetes Association, 2006). Johnson et al. (2006) investigated the health care use and costs for type 1 and type 2 diabetics; they suggest that a majority of health care costs are accrued in the incident year and a large proportion of total diabetes health care expenditure is attributed to people with type 2 diabetes (96%). It is clear that diabetes is diverting scarce resources away from other goods and services. Economic projections show that the burden of diabetes is on the rise due to population

growth, increasing prevalence rates, and an aging population (Honeycutt et al., 2002; Boyle et al., 2001).

2.3 Diabetes and Health Related Quality of Life (HRQL)

People with diabetes have been shown to have a decreased health related quality of life (HRQL) compared to nondiabetics (Maddigan et al., 2004). This reduction in HRQL is even more pronounced with accumulating comorbidities and medical conditions (Maddigan et al., 2006). Studies by Maddigan et al. (2004, 2006), show that stroke, heart disease, depression, and an increasing number of medical conditions all contribute to a decreasing HRQL. Other researchers using different measures such as the EQ-5D found that diabetes is associated with a lower HRQL (Koopmanschap, 2002).

Bowker et al. (2006) reported HRQL outcomes in a cross sectional study using the Canadian Community Health Survey (PUF CCHA) Cycle 1.1 and the Health Utilities Index Mark 3 (HUI3) to assess HRQL in (1) individuals with comorbid cancer and diabetes compared to each individual condition alone and (2) individuals with comorbid cancer and diabetes compared to individuals without either condition. The CCHS surveys individuals 12 years and older. Bowker et al. (2006) found that individuals with comorbid diabetes and cancer had an average HRQL of 0.67 ± 0.30 compared to individuals with diabetes alone who had an average HRQL of 0.78 ± 0.27 and individuals with cancer alone who had an average HRQL 0.78 ± 0.25.

Maddigan et al. (2006), using the CCHS Cycle 1.1 and the HUI3 reports an overall HRQL of 0.78 ± 0.28 for individuals with type 2 diabetes. Additional comorbidities such as cataracts, heart disease, stroke, and depression were associated with lower HRQLs, 0.61, 0.63, 0.67, and 0.68, respectively. Patients with microvascular or macrovascular complications had an HRQL of 0.69 compared to a nondiabetic individuals of the same age (0.80) (Koopmanschap, 2002). If individuals had both complications (macrovascular and microvascular) the HRQL was reduced substantially to 0.59; even patients requiring insulin reported a lower HRQL of 0.62 (Koopmanschap, 2002). Insulin therapy was associated with a severe decline in beta cell function (Turner et al., 1999). Polypharmacy which included insulin use was associated with poor

glycemic control and higher risk for major comorbidities as well as increased health care costs (Willey et al., 2006).

2.4 Pathophysiology of type 2 diabetes mellitus

Obesity is known to be a risk factor in developing diabetes, and is primarily responsible for 2 factors: insulin resistance and insulin deficiency (Felber and Golay, 2002). Obese patients have been found to have permanently elevated plasma free fatty acids (FFA) which are released from visceral fat cells. This increased elevation leads to the impairment of skeletal muscle glycogen synthesis (glucose uptake) which leads to insulin resistance (Felber and Golay, 2002; Petersen and Shulman, 2006). Insulin levels increase in order to compensate for the increased plasma glucose levels resulting in normalization of glucose uptake. However, sustained hyperinsulinemia inhibits insulin secretion and insulin action and ultimately results in a decline of insulin secretion (Felber and Golay, 2002), resulting from beta cell exhaustion. This knowledge reinforces the need for prevention programs which target and reduce obesity as an important risk factor responsible for type 2 diabetes. Lifestyle changes which include healthier diets and increased physical activity have been shown to lead to weight reduction and reversal in insulin resistance and result in the prevention or delay of the onset of diabetes (The Diabetes Prevention Program Research Group, 2002; Pan et al., 1997; Carr et al., 2005; Lindstrom et al., 2003; Ramachandran et al., 2006).

2.5 Economic models and future trends in diabetes mellitus

Diabetes has been recognized as a serious issue at the global level; the World Health Organization (WHO) and the International Diabetes Foundation (IDF) have a joint initiative "Diabetes Action Now!" with a goal of reducing the impact of diabetes and diabetes related chronic diseases of children and adults worldwide (World Health Organization, 2008). In Canada the seriousness of the problem was acknowledged in 1999 with a 5 year, 115 million dollar comprehensive Canadian Diabetes Strategy to help prevent and control the disease (Health Canada, 1999). There is a need for population projections of the incidence, prevalence, and mortality caused by diabetes to inform and direct policies that will reduce or curb the epidemic. Numerous studies have attempted to

model the increases in incidence, prevalence, and costs associated with diabetes. Each has used different methods and assumptions to arrive at a prediction that is as close to reality as possible. Some studies combine prevalence estimates from the literature applied to population projections to produce life tables, while others use Markov modeling, incorporating transition probabilities to arrive at predictions. Studies combining prevalence estimates and population projections to construct life tables have been used on various geographical levels.

2.5.1 Worldwide economic models and future trends

King et al. (1998) projected the global burden of diabetes from 1995 to 2025. The authors used 5 year age and sex specific diabetes prevalence estimates from urban and rural areas of various countries which passed the inclusion criteria of (1) an unbiased population sample and 2) diagnosis follows recommendations of WHO. King et al. (1998) applied the prevalence estimates to United Nations' population estimates and projected the number of adults 20 years old and older for all countries around the world. Assumptions were made in this study due to (1) lack of valid prevalence estimates, (2) data sets with missing prevalence rates for age classes, (3) assumption of risk factors between rural and urban areas for both developing and developed countries, and (4) missing data for urban and rural areas. These global projections suggest that there will be a 35% increase in the worldwide prevalence of diabetes, with the greatest increase in developing countries among 45–64 year olds.

In a similar study more recently, Wild et al. (2004) set out to estimate the global prevalence of diabetes in the years 2000 and 2030. Age and sex specific prevalence estimates were extrapolated to other countries based on geographical proximity, and on ethnic and socioeconomic similarities and applied to United Nations' population estimates for 2000 and 2030. In order to observe the effects of urbanization on the risk of diabetes, urbanization was associated with different risk factors of altered diet, obesity, decreased physical activity, and stress. Projections suggest that the prevalence of diabetes will increase from 2.8% in 2000 to 4.4% in 2030 with a changing demographics to older age groups (> 65 years of age) and with urbanization being the most prominent contributor.

2.5.2 United States economic models and future trends

Mainous et al. (2007) modeled the number individuals with diabetes in the United States and the proportion of persons with diabetes until 2031 using a top-down approach. A number of national surveys were used including the National Health and Nutrition Examination Survey (NHANES: NHANES III 1988–1994, NHANES 1999–2002, NHANES II mortality survey) and the U.S. Census Bureau population projection data. Data on transition states probabilities, migration, mortality, and persons moving into the 20–29 age class were extracted from the surveys and used to model the burden of diabetes (undiagnosed and diagnosed) and the percentage of individuals with diabetes for 10 year intervals. Population data from the NHANES III data were fitted to the NHANES 1999–2002 prevalence projections before any projections were made. Projections predicted that adult diabetes prevalence will rise from 6.3% in 1991 to 14.5% in 2031.

Boyle et al. (2001) projected the number of people with diagnosed diabetes in the U.S. through 2050. The study utilized a top down approach using national U.S. Census Bureau population projections until 2050 and diagnosed diabetes prevalence data from the National Health Interview Survey (NHIS). The National Health Interview Survey is an annual survey which asks a subsample of the respondents whether an individual in their household has diabetes. Diabetes prevalence data were available by sex, race, and age group. The U.S. Census Bureau developed population projections based on a set of assumptions involving fertility rates, life expectancies, and net immigration. Population projections were accomplished by applying prevalence estimates from the NHIS to the U.S. Census Bureau population projections. Sensitivity analysis was done by varying population projection data and projected rates of diabetes prevalence in the United States. Projections predicted an increase of 165% in the number of people living with diabetes above 2000 levels (11 million in 2000 to > 29 million in 2050).

Honeycutt et al. (2003) used Markov modeling to forecast diabetes prevalence through 2050. The developed Markov model consisted of 3 disease states (no diabetes, diabetes, and death) and cycled in 1 year intervals. Transition probabilities differed by age, race, ethnicity, and sex; to increase accuracy of the predictions, forecasts of the number of live U.S. births and net migration were added to the existing cohorts. The U.S.

Census Bureau population projections and the NHIS were used to extract information on base year populations, base year diabetes prevalence, diabetes incidence, estimates of the relative risk of mortality from diabetes, and forecasts of the number of live births, net immigration, and population mortality rates. The model predicted that diabetes prevalence across all ages in the United States will increase from 4.4% in 2000 to 9.7% in 2050, with 39 million people with diagnosed diabetes in 2050. Narayan et al. (2006) observed an increase in the nation's diabetes incidence and a decrease in the relative risk of death for people with diabetes. They revised their original model (Honeycutt et al., 2003) and more recently projected 48.3 million people with diabetes in the United States in 2050 (Narayan et al., 2006).

2.5.3 Canadian economic models and future trends

Ohinmaa et al. (2004) projected the diabetes prevalence and costs in Canada and the provinces from 2000 to 2016. Life tables were constructed using population projections from Statistics Canada, combined with prevalence estimates and incidence from the literature and health care costs from administrative data. Ohinmaa et al. (2004) were able to predict age specific diabetes, health care costs by province, and the distribution of direct health care costs by diabetes status as well as the distribution of health care costs by major diabetic comorbidities. Diabetes in Canada was predicted to increase from 1.4 million in 2000 to 2.4 million in 2016 with a 75% increase in costs in same time frame; 27% of the cost was attributed to cardiovascular diagnosis.

2.6 Diabetes prevention through lifestyle intervention

Remission back to normal glycohemoglobin or nondiabetic glucose tolerance is unlikely after diagnosis of type 2 diabetes; therefore, the effective prevention of diabetes mellitus is preferred over early detection and treatment (Knowler et al., 1995). Lifestyle interventions were always considered important, but their true impact was not understood until recently. Physiologic studies done in the early 1990s supported this hypothesis (Eriksson and Lindgarde, 1991; Pan et al., 1997; Eriksson et al., 1999), and now large RCTs conducted in a number of countries clearly demonstrate the efficacy of lifestyle interventions for prevention in patients at high risk of developing diabetes (The Diabetes

Prevention Program Research Group, 2002; Lindstrom et al., 2003; Ramachandran et al., 2006).

A study investigating the impact of modernization on increasing diabetes prevalence in native Indians found that sedentary occupations were significantly associated with diabetes, indicating that lifestyle may be important in determining the development of diabetes in urban and urbanizing populations (Ramachandran et al., 1999). Eriksson and Lindgarde (1991) tested the feasibility of lifestyle intervention as a long term intervention to prevent or delay the onset of diabetes. The intervention consisted of dietary treatment and/or physical activity or training followed by annual checkups. The authors found that oxygen uptake increased by 10–14%, body weight was reduced by 2.3–3.7%, glucose tolerance was normalized in greater than 50% of participants, and more than 50% of people with diabetes were in remission after a 6 year follow-up. Further, Eriksson and Lindgarde (1991) found that lifestyle intervention reduced blood pressure, lipids, and hyperinsulinaemia, improved glucose responsiveness to glucose loading, and improved glucose tolerance. Improvement in glucose tolerance was found to be correlated with weight reduction and increased fitness (Eriksson and Lindgarde, 1991).

The Da Qing Study investigated the effects of diet and/or exercise on the incidence of diabetes in individuals with impaired glucose tolerance (IGT), individuals at high risk for developing diabetes (Pan et al., 1997). The study had 110,660 participants from 33 health care clinics. Subjects were randomized by clinic to investigate the effects of diet only, exercise only, and diet plus exercise on the incidence of diabetes. Within the diet intervention group, individuals were encouraged to reduce caloric intake to gradually lose weight, with a target weight of 23 kg/m^2. Patients also received individual counseling from the physician concerning food intake, and group counseling sessions were regularly available throughout the treatment. The exercise group participants were encouraged to increase physical activity; group counseling sessions were available to this group throughout the study. Results reveal that treatment groups (diet only, exercise only, diet plus exercise) significantly reduced incidence of diabetes when compared to a control group.

The U.S. Diabetes Prevention Program (DPP) is a goal based program targeted at individuals with impaired glucose tolerance that are at high risk of developing diabetes. The program utilizes lifestyle coaches, case managers, and frequent contact to deliver the programs. Participants each had to achieve a weight loss goal and a physical activity goal of losing 7% of initial body weight, maintaining the newly achieved weight, and being physically active for a minimum of 150 min (2.5 hr) per week (The Diabetes Prevention Program Research Group, 2002). In addition, toolbox strategies, intervention materials, a 16 session core curriculum, and the self monitoring of fat and calorie intake were used to encourage compliance and to tailor the programs to individual backgrounds and preferences. Lifestyle changes were reported to reduce incidence of diabetes by 58% and the number needed to treat (NNT), to prevent, or to delay a case of diabetes was found to be 7 (The Diabetes Prevention Program Research Group., 2002).

The Finnish Diabetes Prevention Study (Lindstrom et al., 2003) further explored the effects of lifestyle intervention on body weight, plasma glucose, and lipids (Eriksson et al., 1999). This multicentered study utilized physicians, nurses, nutritionists, and exercise instructors or physiotherapists to deliver the treatments. Study subjects were recruited by screening of high risk groups. Dietary interventions consisted of seven face-to-face consultations in the first year followed by a consultation every 3 months. Printed material, voluntary group sessions, expert lectures, low fat cooking lessons, and visits to the supermarket were offered to the diet intervention group. The exercise intervention group consisted of individually tailored intensity resistance training, and exercise competitions were used to motivate participants. Follow-up with participants 1 year after and 3 years after the intervention found that time spent physically active did not change, however, more time was spent on leisure time activity. The absolute amount of fats and energy intake decreased in the intervention groups, and the intervention groups exhibited significant improvements in fasting plasma glucose, 2-h plasma glucose, serum total cholesterol, HDL (high density lipoprotein) cholesterol ratio, and serum triglyceride. Ultimately, fewer individuals progressed to diabetes in the intervention group when compared to the control group, 9% and 20%, respectively.

Ramachandran et al. (2006), conducted a community based prospective study of urban Asian Indian subjects in India over 3 years, investigating whether lifestyle

modification (LSM), metformin, and LSM plus metformin are able to prevent or delay the onset of diabetes. The authors randomly assigned individuals to one of four groups: (1) standard health care advice (control), (2) lifestyle modification (LSM), (3) metformin treatment, and (4) LSM plus metformin treatment. Individuals were recruited for the study from a working middle class population in the service industry; subjects were 35–55 years of age, without diabetes or major illnesses. An oral glucose tolerance test (OGTT) was used. Plasma levels were tested 2-h after a glucose load (75 g glucose). World Health Organization criteria for impaired glucose tolerance (IGT) were applied. Individuals who were physically inactive were advised to walk briskly for at least 30 minutes per day and those who were physically active for greater than 30 minutes a day were advised to continue. Diet modification consisted of advice to reduce total calories and refined carbohydrates and fats, to avoid sugar, and to increase intake of fiber rich foods. To encourage motivation and compliance, intervention procedures were explained individually and again 2 weeks later via letter or telephone. Monthly telephone calls were maintained and personal sessions were conducted at 6 month intervals. After 30 months, significant absolute and relative reductions were observed in the LSM, metformin, and LSM plus metformin groups, 28.5%, 28.2%, and 26.4%, respectively. Importantly, no additional benefit was found by combining LSM with metformin treatment.

2.7 Cost effectiveness of diabetes prevention

There is an increasing need to use scarce resources efficiently. Increasing demands for health care from an increasingly older population has put enormous pressure on the health care system to provide fast, effective, high quality care. This situation is complicated even more as numerous drugs and technologies are put into the market, further straining limited resources. Decision makers are faced with how to allocate limited resources to provide the best and most efficient care. Using cost effective analyses to study the costs and consequences of drugs and treatments, decision makers can compare treatments/drugs and decide which are the most efficient.

Diabetes is an issue that is gaining importance, with costs and prevalence rates being predicted to increase and to be a burden on the health care system (Johnson et al., 2007a; Wild et al., 2004; Boyle et al., 2001; Mainous et al., 2007; Honeycutt et al., 2003;

Ohinmaa et al., 2004). There is a need to find solutions that will delay or prevent the onset of diabetes to reduce costs and to improve the quality of life of Canadians. Studies have shown that lifestyle interventions are efficacious in delaying the onset of diabetes (Pan et al., 1997; The Diabetes Prevention Program Research Group, 2002; Lindstrom et al., 2003). Applying cost-effectiveness threshold levels less than $100,000/QALY (quality adjusted life year) as an acceptable threshold (Laupacis et al., 1992), diabetes intervention via lifestyle or pharmacotherapy has been found to be cost-effective (Ramachandran et al., 2007; The Diabetes Prevention Program Research Group, 2003; Herman et al., 2005).

The Diabetes Prevention Program Research Group performed a cost effectiveness analysis on the results of the Diabetes Prevention Program (The Diabetes Prevention Program Research Group, 2003) from health systems and societal perspectives. Lifestyle modification and metformin treatment were found to be cost effective with a cost per QALY of $31,500 and $996,200, respectively, from the health systems perspective and $5,100 and $99,200, respectively, from the societal perspective; these initial results were based on the within trial prevention outcomes. In a continuation of the Diabetes Prevention Program study, Herman et al. (2005) performed a cost effectiveness analysis on lifestyle and metformin interventions using a Markov simulation model to estimate the lifetime progression of disease, cost, and quality of life based on the transition probabilities from the Diabetes Prevention Program. From health system and societal perspectives, lifestyle modification and metformin intervention were found to be cost effective with a cost per QALY of approximately $1,100 and 31,300, respectively, from the health systems perspective and $8,800 and 29,990, respectively, from the societal perspective. Lifestyle intervention was found to be more cost effective than metformin treatment from both perspectives.

More recently, Ramachandran et al., (2007) performed a cost effectiveness analysis on lifestyle and metformin interventions based on the Indian Diabetes Prevention Program (IDPP). This cost effectiveness assessment is different from previous studies for 2 reasons: (1) difference of costs in developing countries and (2) variable availability of resources. Ramachandran et al., (2007), found that lifestyle and metformin interventions were cost effective from the health systems perspective, with a cost per one case of

diabetes prevented for lifestyle modification, metformin treatment plus lifestyle modification, and metformin intervention to be $1,052 (47,341 Indian Rupees (INR)), $1,095 (49,280 INR), and $1,359 (61,133 INR), respectively. As noted earlier, there was no significant benefit observed by combining metformin and LSM.

These studies indicate that lifestyle and pharmacotherapy interventions are cost effective based on clinical settings, conforming to the appropriate thresholds set out by Laupacis et al. (1992). It is important to note that the cost of metformin in these models was considerably higher than is currently available in generic form. These studies all suggest that lifestyle and metformin interventions are efficacious, however, the real questions that face policy makers are: what is the adherence rate of such interventions, what is the availability of interventions to the population, and what are the costs of administering such an intensive individualized program to a large population.

3.0 Research Design and Methods

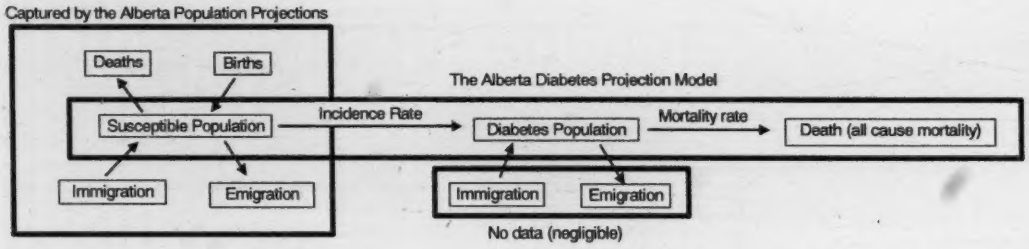
3.1 Alberta Diabetes Projection Model inputs

3.1.1 Model overview

A life table model is used to forecast the prevalence and costs of diabetes from 2006 to 2035. The model was created using incidence, prevalence, and mortality rates from the province of Alberta (Johnson and Vermeulen, 2007) combined with population projections obtained from Alberta Health and Wellness (Public Health Surveillance and Environmental Health, 2007, correspondence with Shaun Malo). Two separate models were created, a female model and a male model, both having 5 year age bands. The variables in the models include starting year prevalence numbers (2005) and incidence and mortality rates sorted by age band and gender.

To model reality as closely as possible, linear regression was performed on incidence and mortality rates to represent increases in yearly incidence and decreases in yearly mortality rates from 1995 to 2005. The projection model begins at 2006 starting with 2005 prevalence data. Each subsequent year, new incident cases are added and deaths are subtracted from the previous year's prevalence numbers within each age band. Costs associated with treatment of diabetes and its related comorbidities were calculated using 1996 Saskatchewan cost data (Simpson et al., 2003), adjusted with the consumer price index to 2005 values. Costs were sorted into their major comorbidities: cardiovascular, renal, ophthalmic, and other. Total costs were calculated by multiplying total prevalent cases of diabetes by costs in each category. This cycle continues annually until 2035. The outputs of the model are incident cases, prevalent cases, deaths, and costs associated with diabetes. The model also incorporates assumptions of the impact of various interventions on incidence and mortality rates used for various cost-effectiveness analyses.

Figure 3.1: General concept of a life table model



3.1.2 Epidemiological data

Data on incidence, prevalence, and mortality were obtained from administrative data from Alberta Health and Wellness through the Alberta Diabetes Surveillance System (ADSS) (Johnson and Vermeulen, 2007). The ADSS role is to facilitate and coordinate the surveillance of diabetes in the province of Alberta and to provide a systematic measurement tool to evaluate the outcomes of health strategies aimed to improve care (ACHORD, 2007).

Alberta has a publicly administered health care insurance plan that ensures Albertans receive universal access to medically necessary health care services. This health insurance system generates person specific administrative data for each procedure billed to the provincial government and each time a diagnosis is made (Johnson et al., 2007b).

Four Alberta Health and Wellness databases were used to assemble data on diabetes and its related comorbidities and complications: the Discharge Abstract Database (hospital morbidity), Alberta Physician Claims Data, the Ambulatory Care Classification System (which includes emergency room encounters), and Vital Statistics (which contains information on mortality) (Johnson et al., 2007b). The 4 data sets were pooled into a single data set hosted by the Alberta Diabetes Surveillance System (ADSS) (Johnson et al., 2007b).

In order to identify a diabetic case from the Alberta Health and Wellness Databases, the NDSS diabetes case definition algorithm was applied. A diabetic case was identified as either (1) one hospitalization with ICD-9 of 250 (diabetes mellitus) for all available data for years 1995 to 2001 or equivalent ICD-10 codes (E10-14) diabetes for the years after 2001/2002 or (2) two physician claims with an ICD-9 code of 250 (DM)

within 2 years (Johnson et al., 2007b). Alberta Health and Wellness data also has information on demographics (age, sex, health region, First Nation status), and health care utilization (hospitalization, physician services, and ambulatory care) was described for diabetic and nondiabetic populations in Alberta (Johnson et al., 2007b). This allowed for the extraction of incidence, prevalence, and mortality of diabetes mellitus cases in Alberta by age, sex, and First Nations status (Johnson et al., 2007b).

Crude incidence, prevalence, and mortality data for each gender were organized and extracted for each year (1995–2005) for each 5 year age band (Appendix A). Data for individuals under 1 year of age was excluded from the analysis due to issues of quality and unreliability of reporting of diabetes in that particular age group.

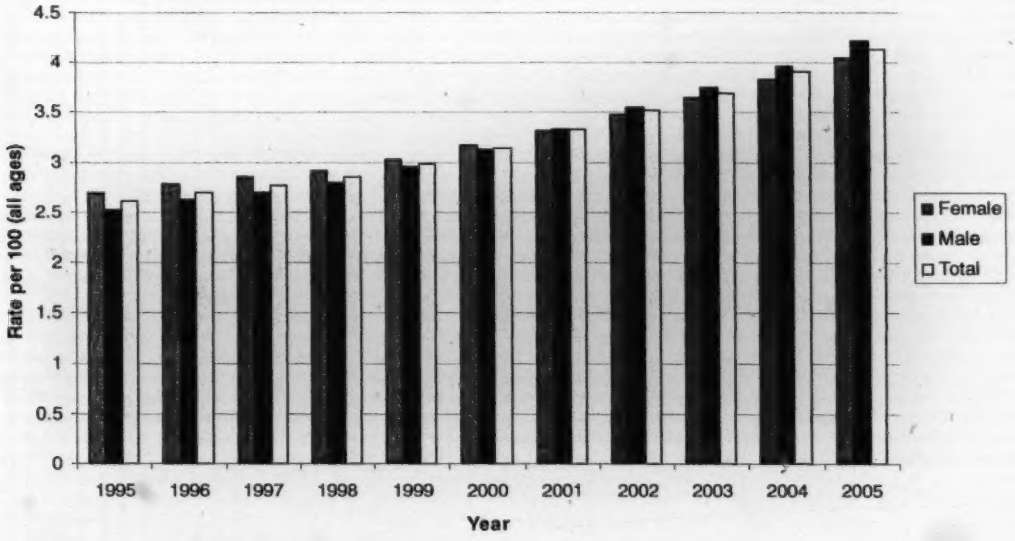
3.1.2.1 Prevalence rates

Prevalence rates were used to measure the number of people with diabetes within an annual time frame. To calculate prevalence rates, the number of existing cases of diabetes within a specific time frame included new cases of diabetes within the specified time frame (Formula 1).

$$(1) Prevalence = \frac{\Sigma of\ people\ with\ existing\ diabetes\ in\ the\ end\ of\ calendar\ year}{Total\ population\ in\ the\ end\ of\ the\ year\ (individuals\ with\ and\ without\ diabetes)}$$

Crude prevalence rates for each gender were calculated for each year (1995–2005) of available data for the appropriate age bands.

Figure 3.2: Summary of crude prevalence rates organized by gender and year for 1995 to 2005 (Johnson and Vermeulen, 2007)



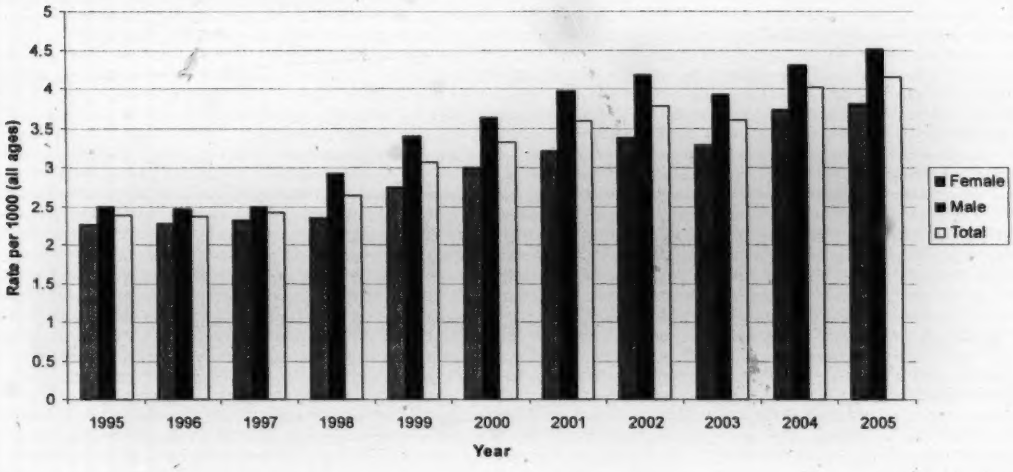
3.1.2.2 Incidence rates

Annual incidence rates were used as a measure of new cases of diabetes arising within a specific time frame. Alberta Health and Wellness database prevalence counts include incident cases and must be adjusted when calculating incidence rates (Formula 2); prevalent cases must be removed from the population at risk and incident cases must be added back in to correct crude incidence rates.

$$(2) Incidence = \frac{\Sigma \text{ of incidence cases of diabetes in current calendar year}}{(\Sigma \text{ total population (diabetics and non diabetics)} - (\text{Prevalent cases at the end of the year}) + (\text{incident cases during the year})}$$

Crude incidence rates for each gender were calculated for each year of available data for the appropriate age bands (1995–2005).

Figure 3.3: Summary of crude incidence rates organized by gender and year for 1995 to 2005 (Johnson and Vermeulen, 2007)



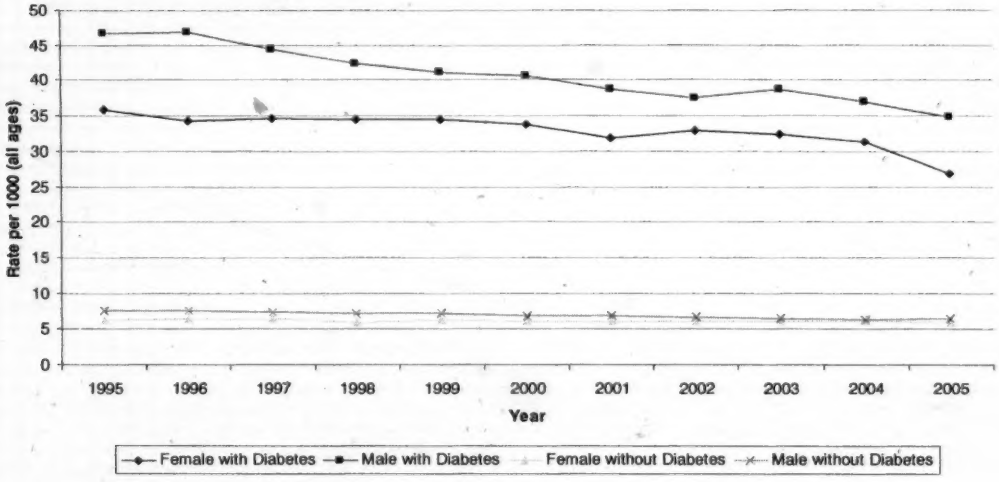
3.1.2.3 Mortality rates

Mortality rates of people with diabetes were calculated for each age band (Formula 3).

$$(3) Mortality\ (with\ diabetes) = \frac{(\Sigma \text{ of deaths among people with diabetes during the current calendar year})}{(\Sigma \text{ of people with diabetes during the end of the calendar year})}$$

Crude mortality rates for each gender were calculated for each year of available data for the appropriate age bands (1995–2005)

Figure 3.4: Summary of crude mortality rates organized by gender and year for 1995 to 2005 (Johnson and Vermeulen, 2007).



3.1.3 Cost data

Saskatchewan cost data from 1996 were used to calculate the costs of diabetes and its related comorbidities. Estimated health care costs are based on Saskatchewan Health administrative data from 34,444 individuals who met the study criteria (Ohinmaa et al., 2004). Saskatchewan has a publicly administered health care insurance plan that ensures residents of Saskatchewan receive universal access to medically necessary health care services (Ohinmaa et al., 2004). This health insurance system generates person specific administrative data for each procedure billed to the provincial government and each time a diagnosis is made. Through the administrative data, individuals with diabetes were identified in the years of 1991 to 1996 by having one of the following records: (1) more than one dispensations record for insulin or an oral anti-diabetic agent, (2) two or more physician claims for diabetes within a 2 year period, or 3) one or more than one hospitalization with a diabetes code as primary, secondary, or tertiary diagnoses using the International Classification of Diseases, Ninth Revision (ICD-9). Specific information on prescription drug use, hospitalizations and physician services, day surgery procedures, and dialysis were obtained from the linkable health care databases of Saskatchewan Health including the prescription drugs database, hospital and physician databases,

hospital service files and the physician services database, respectively (Simpson et al., 2003). Expenditure data was obtained from the hospital service files, physician service files, physician service claims, and other corresponding databases (Simpson et al., 2003).

Data on utilization and expenditure for prescriptions drugs, physician services, hospitalization, day surgery procedures, and dialysis records were calculated for persons in 5 year age bands, and grouped into the major diabetes comorbidities: cardiovascular, renal, ophthalmic, and other, which included amputation related costs (Simpson et al., 2003; Ohinmaa et al., 2004). To observe the specific distribution of costs among incident, prevalent, and death cases, costs were estimated separately for each major comorbidity (Ohinmaa et al., 2004). Ideally, current cost data from Alberta would provide the most accurate projections of the future cost burden of diabetes in Alberta; however, this information was unavailable at this writing. Current costs from Alberta will be updated as soon as they become available.

Saskatchewan data for 1996 was adjusted to 2005 prices using the consumer price index (CPI) obtained from the Bank of Canada (Bank of Canada, 2007) (Formula 4). The average costs (Canadian dollars) of cases in 1996 were found to be $3203, $3342, and $11370 for prevalent, incident, and death cases, respectively. The consumer price index calculations predict that prices will increase by 20% from 1996 levels in 2005 using the CPI. The costs (Canadian dollars) in 2005 were found to be $3853, $4021, and $13677 for prevalent, incident, and death cases, respectively.

$$(4)\ CPI\ Index = \frac{CPI\ (2005)}{CPI\ (1996)}$$

The CPI was obtained from the Bank of Canada website (Bank of Canada, 2007).

The total health care cost in each age band was calculated for the type of case (incident, prevalent, death) and for each major comorbidity by multiplying the number of incident, prevalent, and death cases by the specific total health care costs.

3.2 Alberta Diabetes Projection Model verification

3.2.1 Incidence and mortality rates

A model was constructed assuming increasing diabetes incidence rates and decreasing diabetes mortality rates, a continuation of the trends seen in the ADSS data (1995–2005) (Johnson and Vermeulen, 2007). Epidemiologic projections were extended to 2035 for each sex and for each age group. To model increasing incidence rates as closely as possible to the trends seen in 1995–2005, linear regression was performed on the aggregate level incidence and mortality data, and the yearly marginal increase in incidence rate and the yearly marginal decrease in mortality rate was applied to the projection model. Changes in incidence and mortality were assumed to occur in the first 10 years (2006–2015) and thereafter they were assumed to be constant until 2035.

For modeling purposes, a trend of increasing incidence rates and a trend of decreasing mortality rates were the focus of the projection model. To ensure that the yearly marginal changes in incidence and mortality were correct, the economic projection model was fitted to a decade's (1995–2005) worth of ADSS data. Two verification models were created: incidence and mortality.

3.2.1.1 Incidence rate verification model

A decade's (1995–2005) worth of data, obtained from the ADSS data and using Microsoft Excel 2002, was used to forecast diabetes incidence and mortality rates in Alberta for 10 years (2006–2015) using linear regression. Microsoft Excel 2002 was used to calculate the slopes in incidence and mortality for each gender and each age band (Table 3.1).

To calculate the slopes for incidence in females and males, all the years were included in the regression. In females, incidence in the 25–29 age band was found to have a negative slope and was omitted and replaced with a slope of 0 (Table 3.1). All female and male incidence slopes were used in the model.

The yearly marginal incidence increase as a percentage of 2005 to 2006 incidence rates ranged from 0–6% for females and 1–7% for males (Table 3.1). Within the female population, the lowest yearly marginal incidence increases were found to be in the 20–24, 25–29, and 30–34 years of age groups, with a 0–2% increase in incidence; males were

found to have the lowest rates of increase in the 10–14 and 15–19 years of age groups, with a 1–3% increase (Table 3.1). For both genders, all the age bands seem to have a steady increase of about 4–5%, with a yearly marginal incidence increase of 7% in males 85+ years of age in 2006 (Table 3.1).

Table 3.1: Diabetes incidence increase in 2006 as a % of 2005 incidence rates

Rate Per 100000	Female Incidence (2005)	Marginal Incidence Increase (Slope)	Growth as % of incidence	Male Incidence (2005)	Marginal Incidence increase (Slope)	Growth as % of incidence
1-4	18	1	6%	27	2	6%
5-9	21	1	4%	25	1	5%
10-14	25	1	4%	29	0	1%
15-19	35	1	3%	33	1	3%
20-24	56	0	0%	39	2	5%
25-29	114	0	0%	91	4	4%
30-34	209	3	2%	148	9	6%
35-39	235	9	4%	275	16	6%
40-44	278	11	4%	382	18	5%
45-49	374	14	4%	545	20	4%
50-54	656	29	4%	871	33	4%
55-59	923	42	5%	1179	47	4%
60-64	1141	49	4%	1511	70	5%
65-69	1354	54	4%	1807	78	4%
70-74	1361	69	5%	1726	68	4%
75-79	1348	73	5%	1665	76	5%
80-84	1167	54	5%	1460	65	4%
85+	914	45	5%	1199	80	7%
Total			4%			5%

A verification model was created by applying the yearly marginal increase in incidence to the respective 1995 crude incidence rates; the difference between actual and expected incidence rates for each gender and age band was used to calculate the percentage difference (% difference) (Appendix A). Five year averages between actual and predicted incidence values for each age band and each gender was found to be ± 25% for both males and females.

The model is designed to forecast the patterns of incidence for an additional 10 years, by applying the yearly marginal incidence increase to the respective 2005 incidence rates. The projected female incidence rates in 2015 showed an average increase

across all age bands of 32% from 2006 (Table 3.2). Incidence growth is observed to be the highest in the 1–4 age band with a 48% increase; it steadily decreases to 0% in the 25–29 age band, followed by a small increase of 15% in the 30–34 age band (Table 3.2). For female individuals older than 35 years of age, the incidence increase is quite large with a range of 32% to 46%, with over 40% growth in the 70+ age groups between 2005 and 2015 (Table 3.2).

Table 3.2: Increase in incidence between 2005 and 2015

	Female			Male		
Rate per 10000	2005	2015	% increase from 2005	2005	2015	% increase from 2005
1-4	2	3	48%	3	4	53%
5-9	2	3	35%	3	4	46%
10-14	2	3	35%	3	3	9%
15-19	3	4	26%	3	4	26%
20-24	6	6	2%	4	6	41%
25-29	11	11	0%	9	13	39%
30-34	21	24	15%	15	24	53%
35-39	23	33	34%	28	43	49%
40-44	28	39	34%	38	56	41%
45-49	37	51	32%	55	75	32%
50-54	66	95	38%	87	120	33%
55-59	92	134	39%	118	165	35%
60-64	114	163	37%	151	221	40%
65-69	135	189	34%	181	259	37%
70-74	136	205	43%	173	240	34%
75-79	135	208	46%	167	242	39%
80-84	117	171	40%	146	211	38%
85+	91	136	42%	120	200	56%
Average			32%			39%

Male incidence rates show a different pattern of incidence growth. In females, an increase in age is associated with increasing incidence growth. In males, there is no observable pattern and incidence increases are evenly distributed across all age bands with a range of 26% to 56%; there is a slower incidence growth in the 10–14 years of age group which is projected to experience a 9% growth in incidence from 2006 to 2015 (Table 3.2). The projected male incidence rates in 2015 showed an average increase

across all age bands of 39% from 2005 incidence rates (Table 3.2). Incidence rates increase in both males and females, with higher percentage increases in the age groups 30+ in females and 20+ for males (Table 3.2). Females are projected to experience higher incidence trends than males earlier in life (less than 20 years of age) with an overall average of 36% and 34% from 2005 to 2015, in females and males, respectively (not shown).

3.2.1.2 Mortality rate verification model

The female mortality slopes were calculated using 1996–2004 (omitting 1995 and 2005) data; 1995 and 2005 data were found to be outliers and substantially skewed the results, making the marginal decrease in mortality larger than expected. Male mortality slopes were calculated using 1995–2005 data. The male mortality slopes for the 75–79 and 80–84 age bands were found to be too high and significantly skewed the results of our projections; the male mortality slopes were adjusted by replacing the male values with female slopes from the corresponding age bands.

Under 55 years of age, the yearly change in mortality rates was predicted to be very small and further decrease in mortality rates of the under 55 years of age group would result in a negative mortality rate; the marginal decrease was applied only to mortality rates in the 55–59, 60–69, 70–74, 75–79, 80–84, and the 85+ age bands. The yearly marginal mortality decrease as a percentage of 2005 mortality rates ranged from –1% to –6% in females, and –1% to –5% in males (Table 3.3). Within the female population, the greatest marginal mortality decrease was found to be in the 55–59, and 60–64 age bands with a –6% and –4% decrease (Table 3.3). Males were found to have the largest rate of decrease in the 60–64, 65–69, 70–74, and 75–79 age bands with a –5%, –4%, –4%, and –5% decrease, respectively (Table 3.3). For both genders, the marginal mortality has been observed to have an inverse relationship with increasing age; marginal mortality rates as a percentage of 2005 mortality rates decreased with age, ending with a –1% marginal mortality decrease in the 85+ age band (Table 3.3). Overall, the difference in mortality rates among people with and without diabetes was predicted to get smaller over time.

Table 3.3: Diabetes mortality decrease in 2006 as a percentage of 2005 mortality

	Female Mortality (2005)	Marginal Mortality Decrease (Slope)	Decline as % of mortality	Male Mortality	Marginal Mortality Decrease (Slope)	Decline as % of mortality
55-59	971	-58	-6%	1401	-49	-3%
60-64	1379	-55	-4%	2035	-93	-5%
64-69	2315	-38	-2%	2968	-117	-4%
70-74	3253	-85	-3%	3980	-142	-4%
75-79	5577	-131	-2%	6388	-131	-2%
80-84	8882	-148	-2%	10888	-148	-1%
85+	20431	-212	-1%	24322	-160	-1%
Average			-3%			-4%

A verification model was created by applying the yearly marginal decrease in mortality to 1995 crude mortality rates. The difference between actual and expected mortality rates for each gender and age band was used to calculate the percentage difference (% difference) (Appendix A). A five year average between actual and predicted mortality rates for each age band and each gender was found to be about ±30% for age groups greater than 35 years (not shown).

By applying the yearly marginal mortality rate decrease to the respective 2005 rates for 10 years (2006–2015), the model is designed to forecast the patterns of mortality. The highest decreases in mortality rates were found to be in the 55-59 and 60-64 age groups in females; mortality rate decreases were found to be the highest in the 55-59, 60-64, 65-69, and 70-74 age bands for males. Mortality rates in 2015 are predicted to have an average decrease of –26% from 2006 in both males and females (Table 3.4). Mortality decrease is observed to range from –9% in the 85+ age band to –57% in the 55–59 age band in females (Table 3.4). In males, the observed average decrease in mortality rates was projected to be –26% in 2015 from 2006, and mortality decrease was projected to range from –6% in the 85+ age band to –43% in the 60–64 age band (Table 3.4). There was trend of decreasing mortality rates from 2006 to 2015 in both females and males, with a larger decrease in mortality rate in the 55–74 age bands compared to the 75+ groups (Table 3.4).

Table 3.4: Decrease in mortality from 2005 to 2015

Rate per 1000	Female 2005	Female 2015	% change from 2005	Male 2005	Male 2015	% change from 2005
55-59	10	4	-57%	14	9	-33%
60-64	14	8	-37%	20	11	-43%
65-69	23	19	-15%	30	18	-37%
70-74	33	24	-24%	40	26	-33%
75-79	56	43	-22%	64	51	-19%
80-84	89	74	-15%	109	94	-12%
85+	204	183	-9%	243	227	-6%
Average			-26%			-26%

3.2.1.3 Model verification of incidence and mortality projections obtained from linear regression

Using slopes from the linear regression, the projected slopes obtained for incidence and mortality were analyzed to see the deviation from observed incidence and mortality rates in the ADSS data for each age band. The corresponding marginal increase and decrease in incidence and mortality were applied to 1995 incidence and mortality rates and projected incidence and mortality rates for each subsequent year until 2005. The percentage difference between predicted incidence rates and actual (observed) incidence rates for each age band was calculated. Forecasted incidence rates for the age bands from 1996 to 2005 were average and observed to have a range of about ±40% in females and ±30% in males in various age bands, with a total average (across all age bands) difference of 5% and 1% in males and females, respectively (Table 3.5).

Table 3.5: Percentage difference between forecasted and observed incidence rates for females and males

	Female	Male
1-4	-40%	13%
5-9	-9%	-20%
10-14	-29%	-28%
15-19	2%	-4%
20-24	32%	-22%
25-29	23%	-13%
30-34	18%	1%
35-39	14%	11%
40-44	3%	4%
45-49	3%	0%
50-54	1%	-2%
55-59	7%	9%
60-64	8%	2%
65-69	3%	7%
70-74	8%	10%
75-79	11%	10%
80-84	8%	16%
85+	19%	26%
Total	5%	1%

Forecasted mortality rates from 1996 to 2005 were averaged for the years and observed to range from –9% to +28% in females in various age bands (Table 3.6). In males, forecasted mortality rates from 1996 to 2005 were average for the years and observed to range from –17% to +13% in various age bands (Table 3.6). The total average (across all age bands) difference was observed to be 3% and 0% for females and males, respectively (Table 3.6). The forecasted incidence and mortality rates were good estimates of the overall observed trend of increasing incidence and decreasing mortality.

Table 3.6: Percentage difference between forecasted and observed mortality rates for females and males

	Female	Male
55-59	-9%	13%
60-64	-4%	-17%
65-69	2%	-3%
70-74	28%	-1%
75-79	7%	1%
80-84	9%	0%
85+	-9%	8%
Average	3%	0%

3.2.2 Calculating yearly starting prevalence

Using known prevalence counts, incidence, mortality rates, and population projections for each age band, a life table model was constructed, starting at 2006. Using known prevalent cases of diabetes in 2005 and 2006 population projections, prevalence at the beginning of 2006 was calculated by aging an equal proportion of the age band into the next older age group. For example, to age an equal proportion of the 1–4 age group, one fourth of the population was subtracted from the existing age band and added to the next older age band (5–9). The next age group (5–9) then lost an equal proportion of the population (one fifth) to aging which was added to the next older age group (10–14). This was continued for each age band. The oldest age band, 85+, did not lose any population to aging; however, a proportion of the previous age group was added to the 85+ population. Beginning prevalence for subsequent years will consist of the previous years' year end prevalence cases of diabetes.

3.2.3 Calculating year end prevalence

Prevalence numbers at the end of the year for each age band were calculated by adding the number of new cases due to diabetes that year and subtracting the number of deaths due to diabetes from prevalent diabetes cases (Formula 5).

(5) *Year end prevalence = (Prevalence at beginning of the year) + (New incidence cases) – (mortality among incident and prevalent cases)*

3.2.4 Projected crude prevalence rates

Prevalence rates at the end of each year for each age band were calculated by dividing the number of prevalent cases at the end of the year by the age band population (Formula 6).

(6) $Crude\ prevalence\ rates\ (year\ end) = \frac{Prevalence\ cases\ (year\ end)}{Population\ (year\ end)}$

3.2.5 Intervention effects

Intervention effects were incorporated into the model by varying the change in incidence rate by a certain percentage (e.g., 10%) or varying the change in mortality rate by a certain percentage (eg. 10%) or by doing both procedures (Formulas 7 and 8).

$$(7) Intervention\ effects\ (incidence) = (Baseline\ diabetes\ incidence\ rates \times (1 + percent\ reduction\ in\ incidence\ growth)$$

$$(8) Intervention\ effects(mortality) = (Baseline\ diabetes\ mortality\ rates \times (1 + percent\ increase\ in\ mortality\ growth)$$

3.2.6 Population projection

Alberta population projection data was obtained from the Public Health Surveillance and Environmental Health Branch of Alberta Health and Wellness. The population projection data is based on fertility rates, mortality, and migration rates obtained from 2 sources: (1) the Alberta Health Care Insurance Plan Stakeholder Registry and (2) Alberta Vital Statistics (Public Health Surveillance and Environmental Health Branch, 2007). The Alberta Health Care Insurance Plan Stakeholder Registry lists all Alberta residents eligible for physician and hospital medical coverage; Alberta Vital Statistics regulates all vital events such as births, stillbirths, deaths, adoptions, marriages, and changes of name in Alberta (Public Health Surveillance and Environmental Health Branch, 2007). Raw population data obtained from Alberta Health and Wellness were organized into appropriate age bands for each year until 2035.

3.2.7 Age adjusted prevalence rates

Crude prevalence rates for each gender and each year were age adjusted to eliminate the confounding of the population demographics in crude rates to provide a better measure of how diabetes risk factors contribute to the rapid growth in prevalence rates. Age adjusted calculations were organized by sex, input into STATA 9.2 (student edition), and standardized. The reference population was derived by combining all age specific groups for each year (2005–2035).

3.2.8 Population structure effects on the number of people with diabetes

Two other age standardized rates were calculated to assess the effects of the population structure change (2005–2035) seen in the population projections from Alberta Health and Wellness, on the number of people with diabetes. In order to assess and compare the effects of population structure on the number of people with diabetes, two scenarios were used. The first scenario standardizes all years' prevalence rates to the 2005 population and the results are compared to the second scenario which applied the 2035 population structure to 2005 population numbers for all years. Excel 2003 was used to compute the age adjusted standardized rates.

3.2.9 Sensitivity Analyses

A sensitivity analysis was performed to test the robustness of the model and the results through the use of eight scenarios. The eight different scenarios include:

Table 3.7: Sensitivity Analyses Scenarios

	Scenario	Description
0	Base model	10 year increase in incidence rates and 10 year decrease in mortality rates
1	Constant 2005 incidence and mortality rates for duration of the model (2006–2035)	This scenario models the effects of eliminating all increases in incidence rates and decreases in mortality rates in subsequent years. This assumes that diabetes incidence and mortality rates will remain at 2005 levels.

2	10% increase in the rate of incidence growth in the base model	This scenario models the effects of a higher incidence rate for a duration of 10 years (2006–2015).
3	10% decrease in the rate of incidence growth in base model	This scenario models the effects of a lower incidence rate for a duration of 10 years (2006–2015).
4	Use of nondiabetic mortality slopes (for a duration of 10 years) in the base model	This scenario models the effects of higher mortality rates on diabetes prevalence. People without diabetes experience a slower decline in mortality rates compared to people with diabetes.
5	A 5-year duration of incidence and mortality change in the base model	This scenario models the effects of a 5 year duration of incidence and mortality change (2006–2010) on diabetes prevalence.
6	A 15-year duration of incidence and mortality change in the base model	This scenario models the effects of a 15 year duration of incidence and mortality change (2006–2020) on diabetes prevalence.
7	A 15-year increase in incidence rates and a 5-year decrease in mortality rates in the base model	This scenario models the effects of a 15 year increase in incidence rates and a 5 year decrease in mortality rates. This scenario investigates the effects of prolonged incidence and a short 5 year decline in mortality rates on diabetes prevalence.
8	A 5-year increase in incidence rates and a 15-year decrease in mortality rates in the base model	This scenario models the effects of a 5 year increase in incidence rates and a 15 year decrease in mortality rates. This scenario investigates the effects of prolonged mortality decrease and a short 5 year increase of incidence rates on diabetes prevalence.

4.0 Results

4.1 Alberta Population Projections

The Alberta Health and Wellness projection model showed a 45% and a 46% increase in the total Alberta population from 2005 to 2035 in females and males, respectively. When organized into different age bands, the largest growth in population was observed in the over 60 years of age group with over 100% growth by 2035 in both females and males; in the male 75+ years of age band there is expected to be a 200% increase in the population by 2035 (Table 4.1). Below 60 years of age the population growth is slower at less than 60% from 2005 to 2035 in females and males; both females and males should experience the same growth with a range of 18% to 57% and 18% to 58%, respectively (Table 4.1, Table 4.2). It is interesting to note that the population is expected to decrease in the 5–9, 10–14, 15–19, 40–44, and 45–50 age bands for the years of 2010, 2015, and 2020; however, by 2035 the same substantial growth is seen in the surrounding age bands (Table 4.1, Table 4.2). This negative growth cohort will move through the age bands as they age with new cohorts entering.

Table 4.1: Percentage change in the total female population in Alberta from 2005

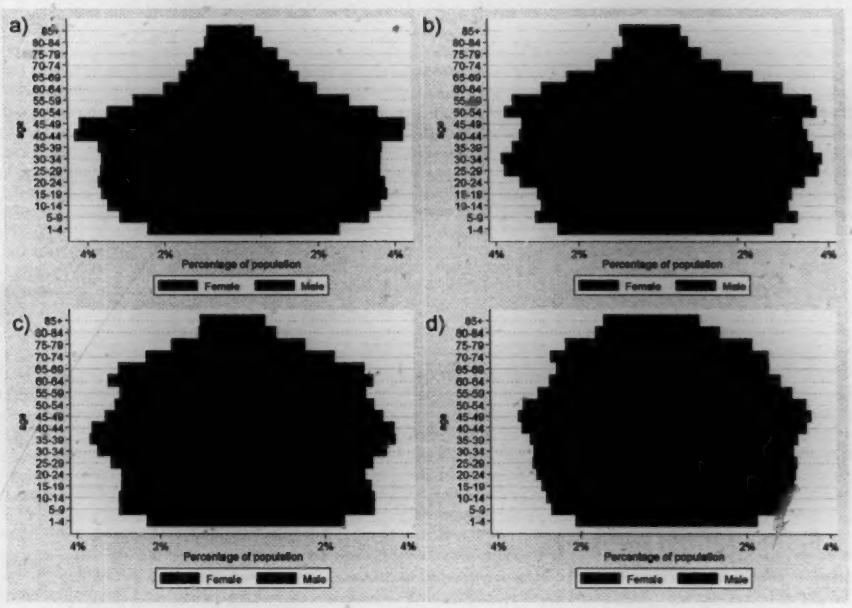
	2010	2015	2020	2025	2030	2035
1-4	13%	22%	26%	27%	25%	26%
5-9	4%	14%	22%	26%	26%	24%
10-14	-3%	-1%	8%	15%	19%	19%
15-19	2%	-2%	-1%	8%	14%	18%
20-24	9%	8%	4%	5%	13%	20%
25-29	17%	22%	21%	16%	17%	26%
30-34	12%	26%	31%	29%	24%	25%
35-39	5%	15%	28%	33%	31%	26%
40-44	-10%	-6%	1%	12%	16%	15%
45-49	5%	-5%	-2%	5%	17%	21%
50-54	22%	28%	15%	19%	28%	42%
55-59	24%	51%	58%	42%	46%	57%
60-64	38%	70%	107%	116%	94%	100%
65-69	23%	68%	107%	151%	163%	136%
70-74	8%	32%	81%	123%	171%	183%
75-79	6%	15%	41%	93%	138%	188%
80-84	9%	16%	25%	53%	110%	160%
85+	19%	34%	46%	58%	86%	143%
Total	**9%**	**18%**	**25%**	**33%**	**39%**	**45%**

Table 4.2: Percentage change in the total male population in Alberta from 2005

	2010	2015	2020	2025	2030	2035
1-4	15%	24%	29%	29%	27%	28%
5-9	3%	16%	24%	28%	28%	26%
10-14	-3%	-1%	10%	17%	21%	21%
15-19	1%	-2%	-1%	9%	16%	20%
20-24	9%	8%	4%	5%	16%	23%
25-29	17%	23%	21%	16%	17%	28%
30-34	11%	25%	30%	28%	23%	25%
35-39	8%	17%	30%	35%	33%	28%
40-44	-7%	-2%	5%	16%	20%	18%
45-49	3%	-6%	-1%	6%	17%	21%
50-54	21%	23%	13%	19%	27%	39%
55-59	26%	51%	53%	41%	48%	58%
60-64	38%	73%	107%	111%	94%	105%
65-69	24%	71%	114%	157%	162%	141%
70-74	8%	34%	86%	133%	180%	185%
75-79	11%	20%	51%	110%	164%	218%
80-84	20%	34%	47%	87%	162%	231%
85+	24%	52%	75%	96%	142%	229%
Total	**10%**	**19%**	**27%**	**34%**	**40%**	**46%**

The population distribution of Alberta will shift from a population that is top shaped to one that is ball shaped—that is, a large majority of the population is below 50 years of age in 2005 whereas the population distribution is relatively spread out across all age groups in 2035 (Figure 1d). This shift in population may have major implications for policy makers.

Figure 4.1: Population distribution of Alberta a) 2005, b) 2015, c) 2025, d) 2035.



4.2 Model output

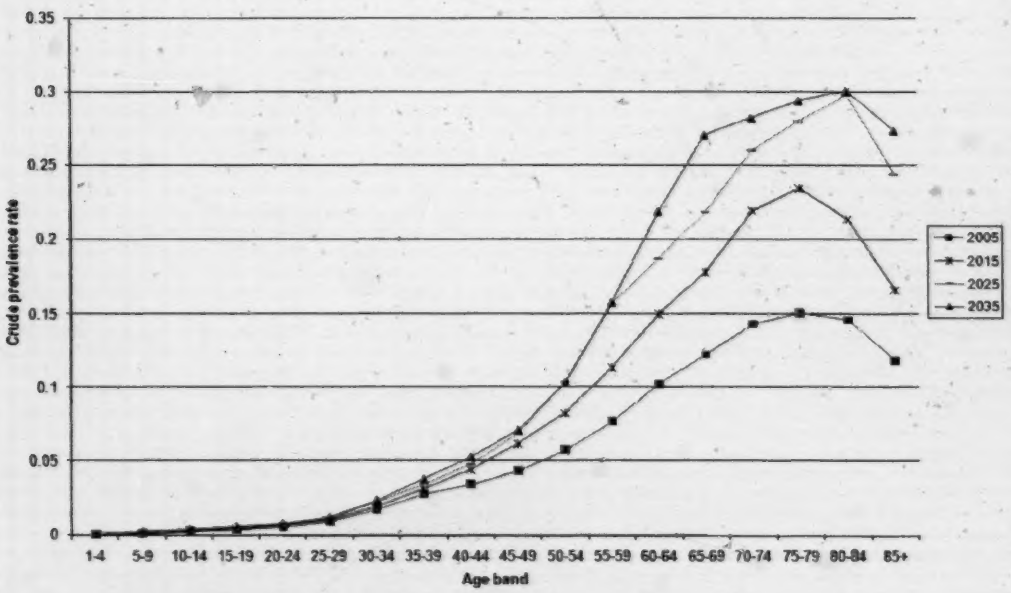
4.2.1 Female diabetes prevalence projections (2006–2035).

The projection model predicts that the overall female diabetes prevalence rate will more than double between 2006 and 2035. Overall female prevalence rates are predicted to be 4.2%, 6.3%, 8.8%, and 10.3% in 2006, 2015, 2025, and 2035, respectively (Table 4.3, Figure 2). The increase in prevalence rates corresponds to a 54811, 122455, and 175890 increase in the number of people with diabetes in 2015, 2025, and 2035, respectively, compared to 2005 (Table 4.3). The largest increase in the number of people with diabetes is expected to be in individuals 55–79 years of age (Table 4.3). The largest increase in prevalence as a percentage of 2005 prevalence rates is expected to be in the 55+ years of age group which is expected to experience nearly 100% increase in prevalence rates in 2035 (Table 4.3). For the under 55 years of age band, a large prevalence increase is expected with a range of 32% to 81%, with a 110% increase in the 1–4 age band (Table 4.3).

Table 4.3: Female prevalence rates and counts as a percentage increase from 2005

	2005	People with diabetes	2015	% increase from 2005	People with diabetes	2025	% increase from 2005	People with diabetes	2035	% increase from 2005	People with diabetes
1-4	0.05%	42	0.10%	80%	92	0.11%	108%	110	0.11%	110%	110
5-9	0.15%	146	0.20%	37%	229	0.24%	67%	306	0.26%	76%	321
10-14	0.30%	330	0.33%	9%	356	0.38%	26%	479	0.41%	37%	536
15-19	0.39%	451	0.49%	26%	556	0.55%	42%	688	0.59%	52%	807
20-24	0.56%	667	0.67%	19%	856	0.78%	38%	964	0.80%	42%	1132
25-29	0.93%	1080	1.05%	13%	1490	1.21%	30%	1634	1.23%	32%	1798
30-34	1.74%	2005	1.94%	12%	2815	2.23%	28%	3316	2.36%	36%	3406
35-39	2.78%	3273	3.11%	12%	4199	3.45%	24%	5386	3.79%	37%	5637
40-44	3.47%	4763	4.44%	28%	5704	4.79%	38%	7389	5.25%	51%	8283
45-49	4.34%	5798	6.15%	42%	7786	6.79%	56%	9551	7.03%	62%	11357
50-54	5.73%	6318	8.25%	44%	11673	10.42%	82%	13635	10.35%	81%	16163
55-59	7.63%	6784	11.39%	49%	15273	15.68%	105%	19735	15.81%	107%	22103
60-64	10.23%	6500	15.05%	47%	16274	18.75%	83%	25733	21.87%	114%	27802
65-69	12.27%	6194	17.83%	45%	15140	21.84%	78%	27697	27.06%	121%	32273
70-74	14.33%	6341	21.95%	53%	12844	26.01%	82%	25674	28.23%	97%	35339
75-79	15.11%	5695	23.46%	55%	10168	27.98%	85%	20318	29.43%	95%	31984
80-84	14.63%	4237	21.35%	46%	7140	29.77%	103%	13198	30.11%	106%	22637
85+	11.85%	3219	16.65%	40%	6059	24.41%	106%	10485	27.35%	131%	18047
Total	4.00%	63843	6.32%	58%	118654	8.81%	120%	186299	10.39%	159%	239734
Diff from 2005					54811			122455			175890
% change from 2005					86%			192%			276%

Figure 4.2: Female prevalence rates in different age groups for 2005, 2015, 2025 and 2035.



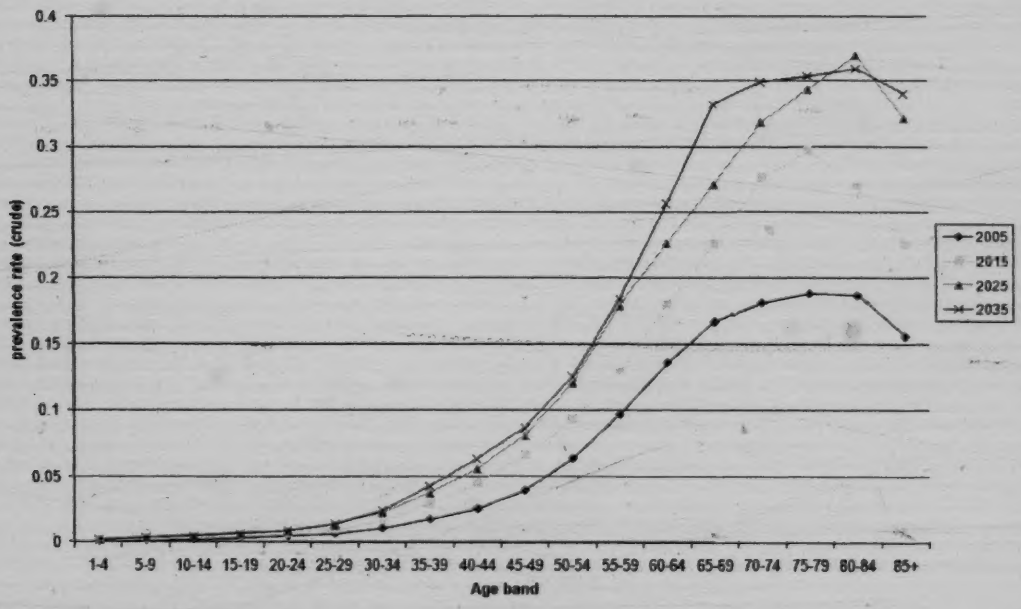
4.2.2 Male diabetes prevalence projections (2006–2035)

The projection model shows that crude overall male diabetes prevalence rates will more than double between 2006 and 2035. Male prevalence rates are expected to be 4.4%, 7.0%, 10.0%, and 11.8% in 2006, 2015, 2025, and 2035, respectively (Table 4.4, Figure 3). The increase in prevalence rates corresponds to a 65867, 146090, and 205853 increase in the number of people with diabetes in 2015, 2025, and 2035, compared to 2005 (Table 4.4). The largest increase in people with diabetes will be found in individuals 55–79 years of age (Table 4.4). The pattern of diabetes prevalence increase in specific age bands is observed to differ between men and women. The prevalence increase in males is observed to be high over all age bands, nearing 100% increase by 2035 in the 25+ years of age band (Table 4.4). The diabetes prevalence increase is also large in the under 25 years of age group at 78% to 93%, with a 130% and 135% increase in prevalence in the 1–4 and 5–9 age bands, respectively (Table 4.4).

Table 4.4: Male prevalence rates and counts as a percentage increase from 2005

	2005	People with Diabetes	2015	% increase from 2005	People with diabetes	2025	% increase from 2005	People with diabetes	2035	% increase from 2005	People with diabetes
1-4	0.08%	62	0.15%	96%	150	0.17%	128%	182	0.17%	130%	182
5-9	0.15%	164	0.27%	74%	331	0.34%	121%	464	0.36%	135%	488
10-14	0.26%	298	0.36%	41%	417	0.45%	74%	608	0.49%	93%	693
15-19	0.37%	449	0.49%	34%	585	0.59%	60%	786	0.66%	78%	955
20-24	0.49%	583	0.64%	32%	836	0.82%	68%	1032	0.87%	78%	1272
25-29	0.67%	780	1.03%	52%	1460	1.33%	97%	1783	1.38%	105%	2044
30-34	1.08%	1254	1.69%	56%	2455	2.20%	104%	3270	2.40%	123%	3479
35-39	1.74%	2038	2.97%	70%	4076	3.73%	114%	5874	4.21%	142%	6302
40-44	2.58%	3477	4.52%	75%	5992	5.59%	117%	8744	6.32%	145%	10077
45-49	3.95%	5381	6.66%	69%	8561	8.10%	105%	11728	8.72%	121%	14368
50-54	6.39%	7305	9.36%	46%	13167	12.08%	89%	16412	12.58%	97%	20035
55-59	9.76%	8850	12.95%	33%	17693	17.89%	83%	22852	18.44%	89%	26472
60-64	13.67%	8740	18.01%	32%	19911	22.64%	66%	30558	25.66%	88%	33570
65-69	16.69%	8176	22.62%	36%	18980	27.09%	62%	34078	33.20%	99%	39252
70-74	18.13%	7470	27.67%	53%	15322	31.81%	75%	30495	34.95%	93%	41105
75-79	18.86%	5893	29.70%	57%	11163	34.38%	82%	22552	35.38%	88%	35175
80-84	18.69%	3579	27.03%	45%	6937	36.99%	98%	13231	35.95%	92%	22791
85+	15.62%	1959	22.57%	45%	4292	32.12%	106%	7900	34.02%	118%	14053
Total	4.18%	66459	7.02%	68%	132326	10.00%	139%	212550	11.77%	181%	272312
Diff from 2005					65867			146090			205853
% change from 2005					99%			220%			310%

Figure 4.3: Male prevalence rates in different age groups for 2005, 2015, 2025 and 2035.



4.2.3 Cost Projections

4.2.3.1 Costs by type of comorbidity

From the female projection model, diabetes and its related comorbidities and other health care costs of diabetes will cost the Alberta government $479, $795, and $1081 million dollars in 2015, 2025, and 2035, respectively (Table 4.5, Table 4.6). The percent change of total costs from 2005 is expected to be 88%, 212%, and 324% in 2015, 2025, and 2035, respectively (Table 4.5, Table 4.6). The largest increases in cost are expected to be ophthalmic costs with a 368% increase followed by cardiovascular costs with an increase of 363% in 2035 compared to 2005 (Table 4.6). Ophthalmic and cardiovascular costs will account for 3% and 28%, respectively, of total cost, with the largest proportion attributed to the "other" category which includes amputations and all other diabetes related and unrelated costs (not shown).

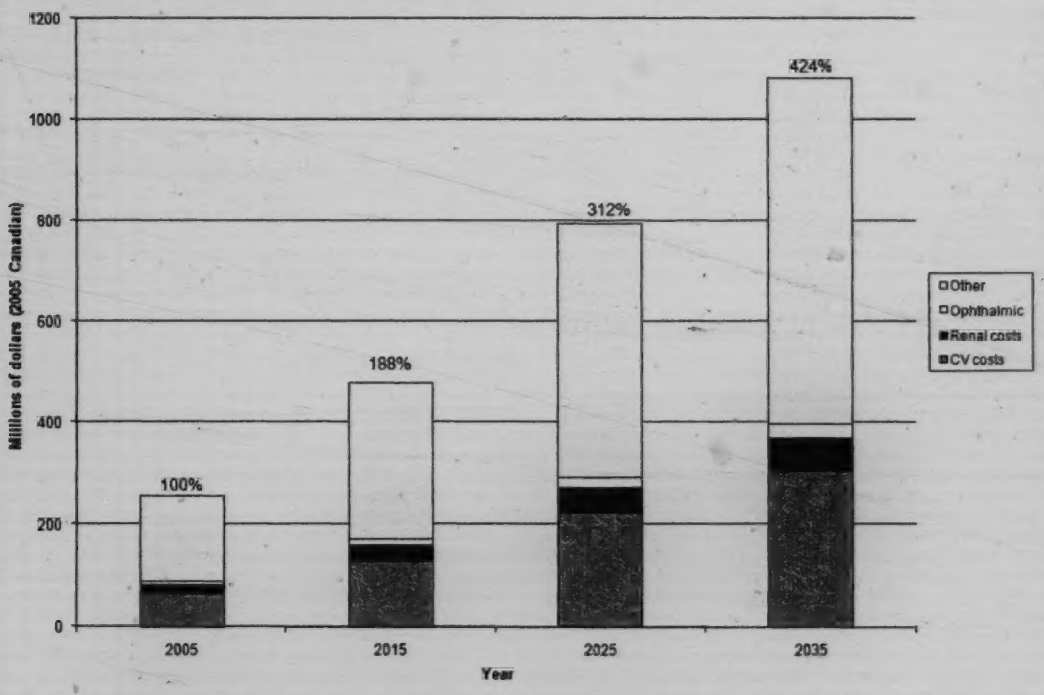
Table 4.5: Total health care costs and percentage increases by case type from 2005 for the female diabetes population

	2005	2015	% increase from 2005	2025	% increase from 2005	2035	% increase from 2005
Prevalent	206	395	92%	666	224%	901	338%
Incident	22	40	80%	48	119%	56	155%
Mortality	27	45	65%	81	195%	124	352%
Total	255	479	88%	795	212%	1081	324%

Table 4.6: Total health care costs and percentage increases by type of co-morbidity from 2005 for the female diabetes population

	2005	2015	% increase from 2005	2025	% increase from 2005	2035	% increase from 2005
CV costs	66	129	96%	221	235%	304	362%
Renal costs	18	32	80%	50	183%	65	264%
Ophthalmic	6	12	93%	20	236%	29	368%
Other	165	307	86%	503	204%	683	313%
Total	255	479	88%	795	212%	1081	324%

Figure 4.4: Total cost of health care for the female diabetes population by type of comorbidity for 2005, 2015, 2025 and 2035.



Percentage = percentage growth in relation to 2005 health care costs

From the male projection model, diabetes and its related comorbidities and other health care costs of diabetes will cost the Alberta government $536, $903, and $1216 million dollars in 2015, 2025, and 2035, respectively (Table 4.7, Table 4.8). The percent change of total costs from 2005 was found to be 98%, 233%, and 349% in 2015, 2025, and 2035, respectively (Table 4.7, Table 4.8). The largest increases in cost are predicted to be ophthalmic costs with a 395% increase followed by cardiovascular costs with an increase of 374% in 2035 compared to 2005 (Table 4.8). Ophthalmic and cardiovascular costs will account for 3% and 28%, respectively, of total cost, with the 63% of costs being attributed to the "other" category which includes amputations and all other diabetes related and unrelated costs (not shown).

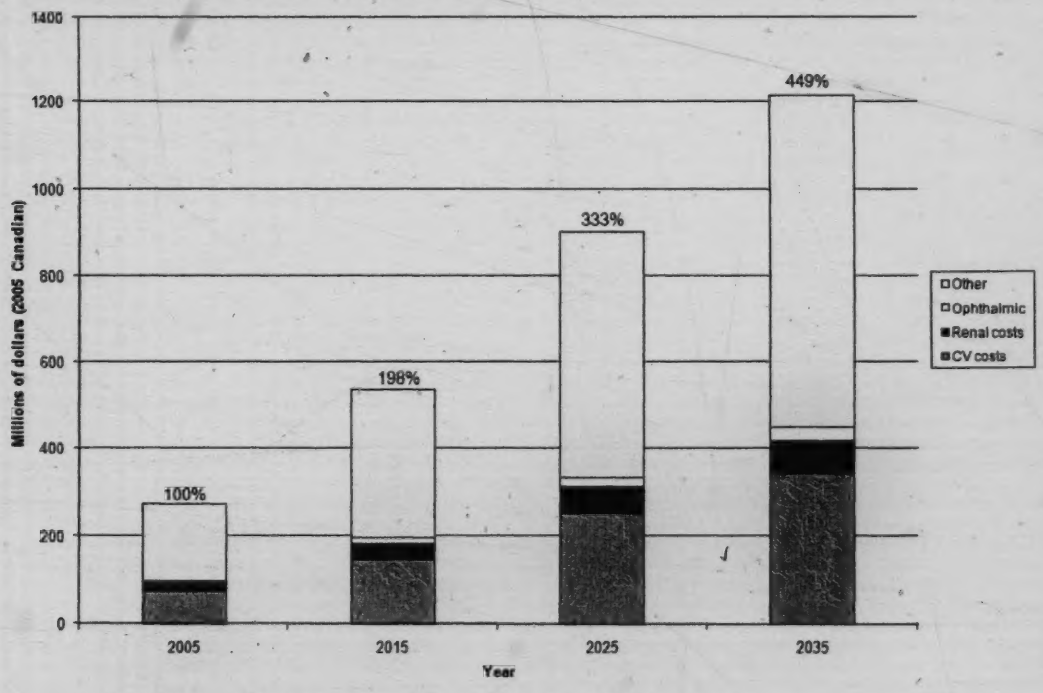
Table 4.7: Total health care costs and percentage increases by case type from 2005 for the male diabetes population

	2005	2015	% increase from 2005	2025	% increase from 2005	2035	% increase from 2005
Prevalent	229	435	104%	748	250%	1002	369%
Incident	27	46	85%	55	122%	63	153%
Mortality	37	56	71%	100	208%	152	366%
Total	292	536	98%	903	233%	1216	349%

Table 4.8: Total health care costs and percentage increases by type of co-morbidity from 2005 for the male diabetes population

	2005	2015	% increase from 2005	2025	% increase from 2005	2035	% increase from 2005
CV costs	72	145	101%	250	248%	341	374%
Renal costs	20	38	91%	61	207%	78	293%
Ophthalmic	6	13	104%	23	259%	31	395%
Other	173	341	97%	569	229%	766	343%
Total	271	536	98%	903	233%	1216	349%

Figure 4.5: Total cost of health care for the male diabetes population by type of comorbidity for 2005, 2015, 2025 and 2035.

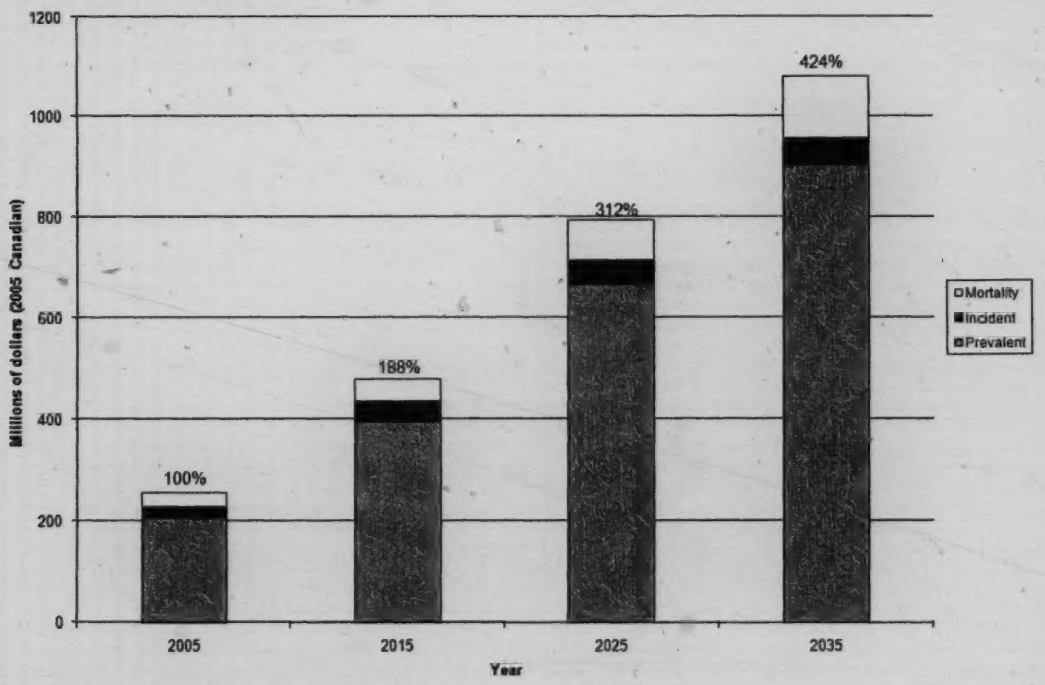


Percentage = percentage growth in relation to 2005 health care costs

4.2.3.2 Cost by case type

From the female projection model, the largest proportion of costs is attributed to diabetes prevalent cases which comprise 81% of the total health costs in 2005 and 83% of the total health costs in 2035 (Figure 4.6). The largest cost increases are attributed to diabetes mortality cases, with a 352% increase in 2035 from 2005 followed by prevalent cases with an increase of 338% in 2035 compared to 2005 (Table 4.5). Incident case costs are expected to increase by 155% in 2035 from 2005 (Table 4.5)

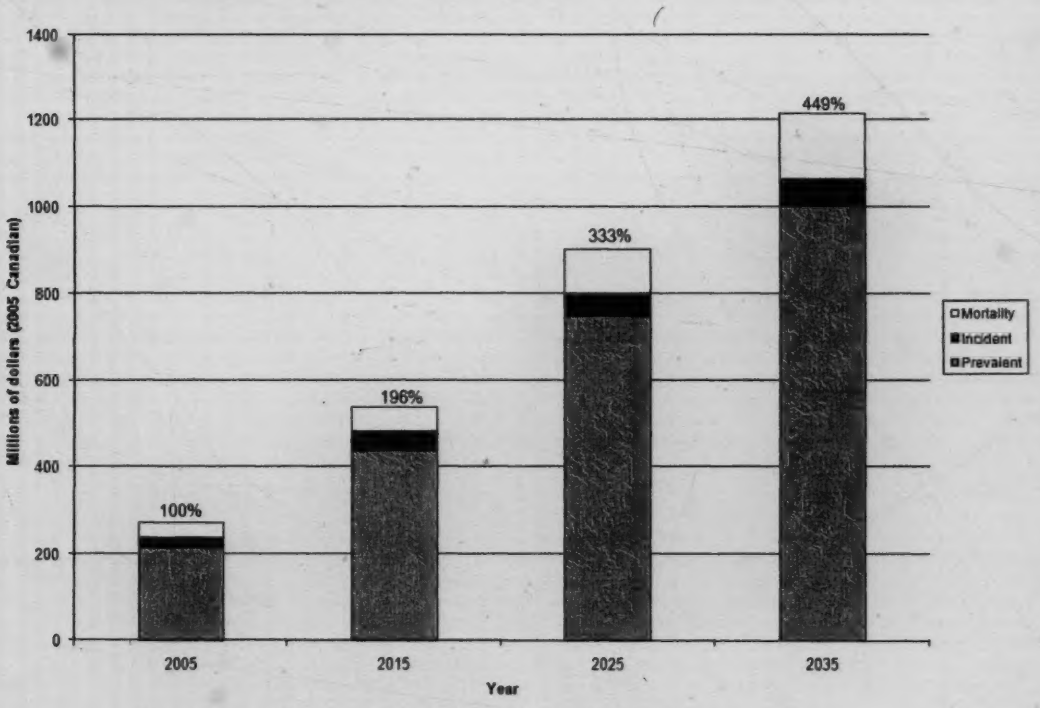
Figure 4.6 Total cost of health care for the female diabetes population by case type for 2005, 2015, 2025 and 2035.



Percentage = percentage growth in relation to 2005 health care costs

From the male projection model, the largest proportion of costs is attributed to diabetes prevalent cases which comprise 79% of the total health costs in 2005 and 82% of the total health costs in 2035 (Table 4.7, Figure 4.7). The largest cost increases are attributed to diabetes prevalent cases with a 369% followed by diabetes mortality cases costs with an increase of 366% in 2035 from 2005 (Table 4.7). Incident diabetes case costs are expected to increase by 153% in 2035 from 2005 (Table 4.7).

Figure 4.7: Total cost of health care for the male diabetes population by case type for 2005, 2015, 2025 and 2035.



Percentage = percentage growth in relation to 2005 health care costs

4.3 Combined prevalence rates and costs

4.3.1 Prevalence rates

From the projection model, the overall crude diabetes prevalence rate for the entire Alberta population is predicted to start from 4% in 2005 and reach 11.5% in 2035, a 188% increase in the overall diabetes prevalence rate (Figure 4.8; Table 4.9). Age specific diabetes prevalence rates (Figure 4.9; Table 4.10), for the entire Alberta population are predicted to be highest in the 75–80 years of age band, followed by the 70–74, 64–69, and the 60–64 years of age bands, with crude prevalence rates of 33%, 32%, 31%, and 30%, respectively (Table 4.10).

Table 4.9: Diabetes prevalence for the entire diabetes population (females and males)

Year	Diabetes prevalence rate
2005	4.09%
2006	4.28%
2007	4.48%
2008	4.70%
2009	4.93%
2010	5.18%
2011	5.45%
2012	5.73%
2013	6.03%
2014	6.34%
2015	6.67%
2016	6.99%
2017	7.30%
2018	7.60%
2019	7.89%
2020	8.17%
2021	8.43%
2022	8.69%
2023	8.94%
2024	9.18%
2025	9.41%
2026	9.62%
2027	9.83%
2028	10.02%
2029	10.21%
2030	10.38%
2031	10.54%
2032	10.69%
2033	10.83%
2034	10.96%
2035	11.08%

Table 4.10: Age-specific diabetes prevalence rates for entire diabetes population (females and males)

	2005	2015	2025	2035
1-4	0.07%	0.12%	0.14%	0.14%
5-9	0.15%	0.24%	0.29%	0.31%
10-14	0.28%	0.34%	0.41%	0.45%
15-19	0.38%	0.49%	0.57%	0.63%
20-24	0.52%	0.66%	0.80%	0.83%
25-29	0.80%	1.04%	1.27%	1.30%
30-34	1.41%	1.81%	2.22%	2.38%
35-39	2.26%	3.04%	3.59%	4.00%
40-44	3.03%	4.48%	5.19%	5.79%
45-49	4.14%	6.41%	7.46%	7.89%
50-54	6.07%	8.80%	11.27%	11.48%
55-59	8.71%	12.18%	16.79%	17.14%
60-64	11.95%	16.54%	20.68%	23.80%
65-69	14.44%	20.21%	24.46%	30.12%
70-74	16.17%	24.73%	28.87%	31.48%
75-79	16.81%	26.36%	31.02%	32.28%
80-84	16.25%	23.81%	32.99%	32.78%
85+	13.04%	18.68%	27.21%	29.92%
Total	4.09%	6.67%	9.41%	11.08%

Figure 4.8: Total crude diabetes prevalence rate in Alberta over time.

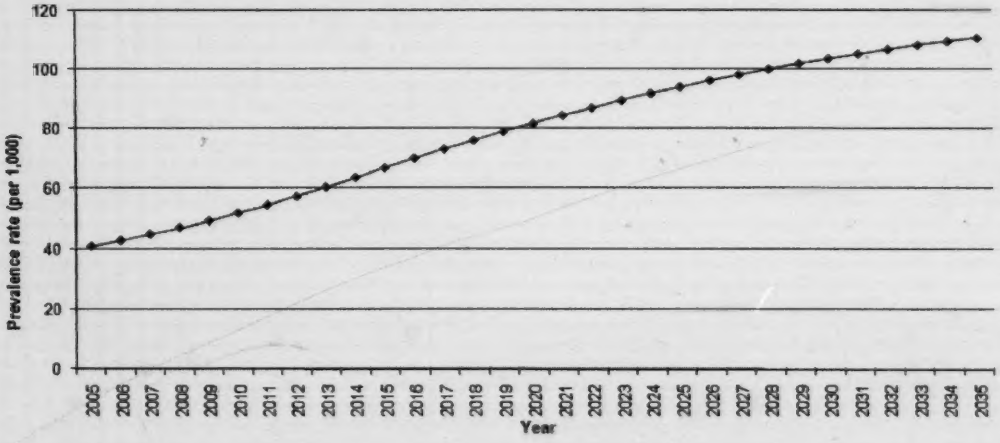
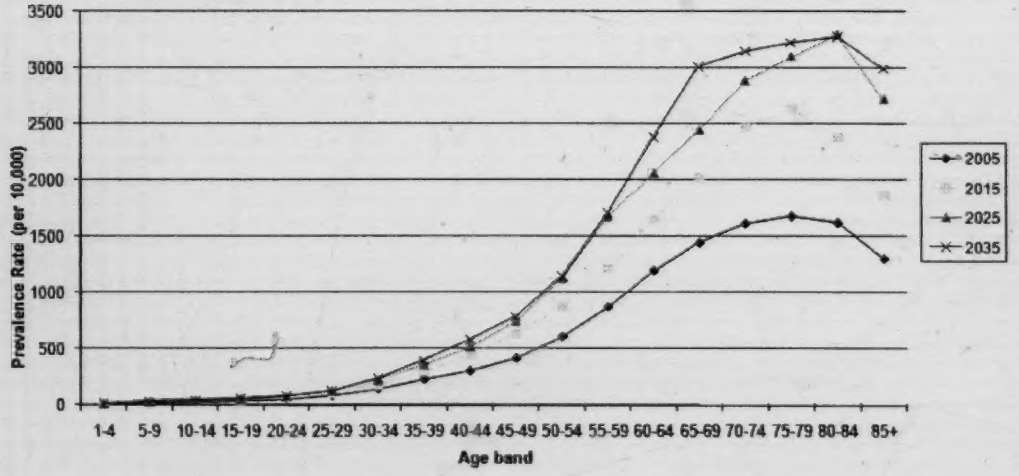


Figure 4.9: Total crude diabetes prevalence rate organized by age band for 2005, 2015, 2025 and 2035.



4.3.2 Total costs

From the diabetes projection model, diabetes, its related comorbidities, and other diabetes-related health care costs will cost the Alberta government 1016, 1698, and 2297 million dollars, respectively. The percent cost changes from 2005 levels are expected to be 93%, 223%, and 337% in 2015, 2025, and 2035, respectively (Table 4.11; Table 4.12). The largest cost increases are associated with ophthalmic costs followed by cardiovascular costs, with 382% and 368% increases in 2035 from 2005 levels (Table 4.12). Renal costs are expected to increase at 279%. Other costs will account for the largest proportion of costs, which include amputations and diabetes and non diabetes related cost, at 63% in 2035, followed by cardiovascular, renal, and ophthalmic costs accounting for 28%, 6%, and 3% of total health care costs (Figure 4.11).

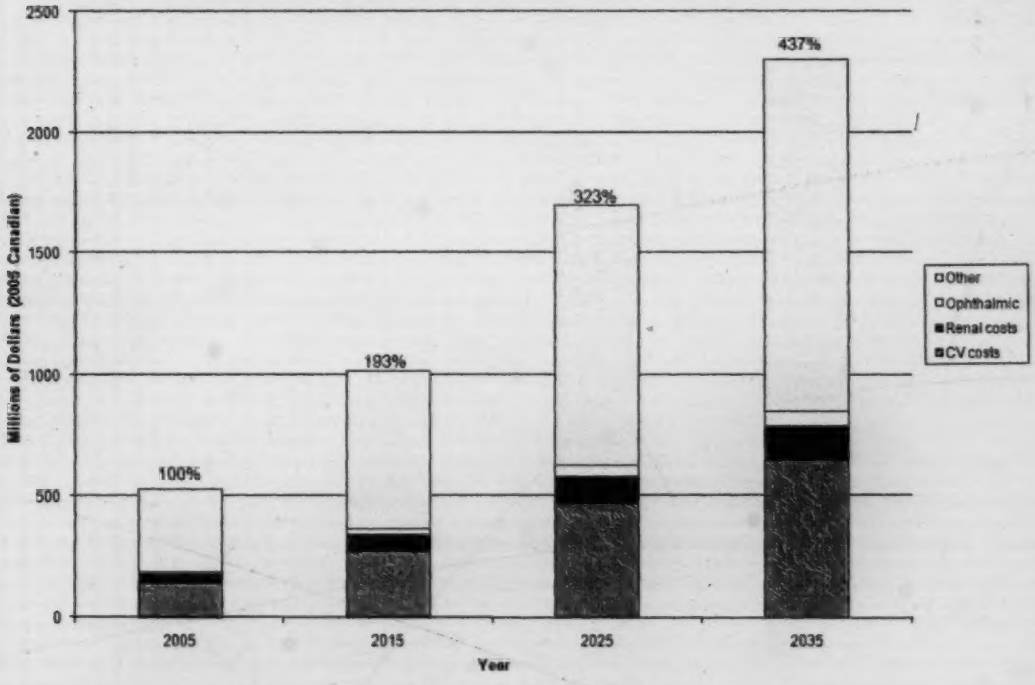
Table 4.11: Total health care costs and percentage increases by case type from 2005 for the entire (female and male) diabetes population

	2005	2015	2025	2035
Prevalent	419	825	1400	1882
Incident	47	84	102	117
Mortality	60	100	179	273
Total	526	1010	1681	2272
% increase		92%	220%	332%

Table 4.12: Total health care costs and percentage increases by type of co-morbidity from 2005 for the entire (female and male) diabetes population

	2005	2015	2025	2035
CV costs	138	272	466	638
Renal costs	38	69	110	141
Ophthalmic	12	25	43	59
Other	338	644	1062	1434
Total	526	1010	1681	2272
% increase		92%	220%	332%

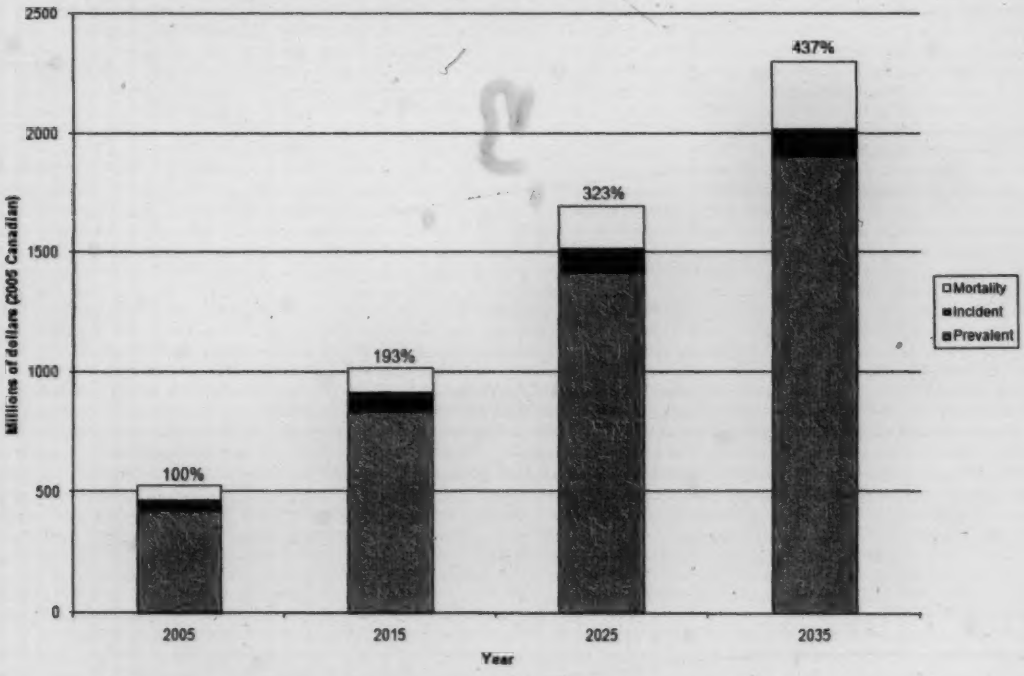
Figure 4.10: Total health care costs and percentage increase by type of comorbidity for the Alberta population for 2005, 2015, 2025 and 2035.



Percentage = percentage growth in relation to 2005 health care costs

From the Alberta projection model, the largest proportion of costs is attributed to diabetes prevalent cases comprising of 80% of total costs in 2005 and 83% of total costs in 2035 (Figure 4.11; Table 4.11). The largest cost increases were attributed to mortality cases, a 360% increase in 2035 from 2005, followed by diabetes prevalent cases with an increase of 354% in 2035 from 2005 (Table 4.5; Table 4.11). Diabetes incident case costs are expected to increase by 154% in 2035 from 2005 (Table 4.5; Table 4.11).

Figure 4.11: Total health care costs and percentage increase by case type for the Alberta population for 2005, 2015, 2025 and 2035.



Percentage = percentage growth in relation to 2005 health care costs

4.4 Age adjusted prevalence rates

The projection model set out to answer the question "how will the diabetes prevalence change with the changing population structure of Alberta from 2005 to 2035, if current trends continue?" However, the crude diabetes prevalence rates stated above are confounded by population effects, and the true increase in diabetes prevalence is masked by the changing demographics of the Alberta population (Figure 5a–d). The age adjusted prevalence rates are calculated based on a standardized population eliminating the population effects on prevalence rates. Age adjusted and crude prevalence rates are predicted to increase by 93.6% and 160.0%, respectively, in females and 100% and 180.9%, respectively, in males (Table 4.13, Table 4.14). Changing demographics and population effects contribute to a 66.4% and 80.9% respective increase in diabetes prevalence rates in the Alberta population.

Table 4.13: Female age adjusted prevalence rates for various scenarios

	crude	age adjusted - pooled	Age adjusted rates (Adjusted to 2005 population)	(2035 pop structure - applied to 2005 population)
2005	4.0%	4.7%	4.0%	5.3%
2006	4.2%	4.9%	4.1%	5.5%
2007	4.4%	5.1%	4.3%	5.7%
2008	4.5%	5.2%	4.4%	5.9%
2009	4.8%	5.4%	4.6%	6.1%
2010	5.0%	5.6%	4.7%	6.4%
2011	5.2%	5.9%	4.9%	6.6%
2012	5.5%	6.1%	5.1%	6.9%
2013	5.7%	6.3%	5.3%	7.1%
2014	6.0%	6.5%	5.5%	7.4%
2015	6.3%	6.8%	5.7%	7.7%
2016	6.6%	7.0%	5.9%	8.0%
2017	6.9%	7.2%	6.0%	8.2%
2018	7.2%	7.4%	6.2%	8.4%
2019	7.4%	7.6%	6.3%	8.6%
2020	7.7%	7.7%	6.5%	8.8%
2021	7.9%	7.9%	6.6%	9.0%
2022	8.2%	8.0%	6.7%	9.2%
2023	8.4%	8.2%	6.8%	9.3%
2024	8.6%	8.3%	6.9%	9.4%
2025	8.8%	8.4%	7.0%	9.6%
2026	9.0%	8.5%	7.1%	9.7%
2027	9.2%	8.6%	7.2%	9.8%
2028	9.4%	8.7%	7.2%	9.9%
2029	9.6%	8.8%	7.3%	10.0%
2030	9.7%	8.9%	7.3%	10.1%
2031	9.9%	8.9%	7.4%	10.1%
2032	10.0%	9.0%	7.4%	10.2%
2033	10.1%	9.0%	7.5%	10.3%
2034	10.3%	9.1%	7.5%	10.3%
2035	10.4%	9.1%	7.6%	10.4%

Table 4.14: Male age adjusted prevalence rates for various scenarios

	crude	age adjusted - pooled	Age adjusted rates (Adjusted to 2005 population)	(2035 pop structure - applied to 2005 population)
2005	4.2%	5.2%	4.2%	6.0%
2006	4.4%	5.4%	4.3%	6.2%
2007	4.6%	5.6%	4.5%	6.4%
2008	4.9%	5.8%	4.7%	6.6%
2009	5.1%	6.0%	4.9%	6.9%
2010	5.4%	6.3%	5.0%	7.2%
2011	5.7%	6.5%	5.3%	7.5%
2012	6.0%	6.8%	5.5%	7.8%
2013	6.3%	7.0%	5.7%	8.1%
2014	6.7%	7.3%	5.9%	8.4%
2015	7.0%	7.6%	6.1%	8.7%
2016	7.4%	7.9%	6.4%	9.0%
2017	7.7%	8.1%	6.6%	9.3%
2018	8.0%	8.3%	6.8%	9.6%
2019	8.4%	8.5%	6.9%	9.8%
2020	8.7%	8.7%	7.1%	10.0%
2021	9.0%	8.9%	7.2%	10.2%
2022	9.2%	9.1%	7.4%	10.4%
2023	9.5%	9.2%	7.5%	10.6%
2024	9.8%	9.4%	7.6%	10.7%
2025	10.0%	9.5%	7.7%	10.9%
2026	10.2%	9.6%	7.8%	11.0%
2027	10.5%	9.7%	7.9%	11.1%
2028	10.7%	9.8%	8.0%	11.2%
2029	10.9%	9.9%	8.0%	11.3%
2030	11.0%	10.0%	8.1%	11.4%
2031	11.2%	10.1%	8.2%	11.5%
2032	11.4%	10.2%	8.2%	11.6%
2033	11.5%	10.2%	8.3%	11.6%
2034	11.7%	10.3%	8.3%	11.7%
2035	11.8%	10.4%	8.4%	11.8%

4.5 Population structure effects

The population structure is predicted to change from 2005–2035 (Figure 5). To isolate the effects of aging on diabetes prevalence, two scenarios were considered. The change in population structure to older age bands will result in a redistribution of people with diabetes (Table 4.15, Table 4.16). In the younger age bands (male and female), less than 54 years of age, there are few people with diabetes in the 2005 population structure scenario (Figure 5a) compared to the scenario that results when the 2035 population structure is applied to the 2005 population. In the population greater than 55 years of age, the trend toward older age groups is expected to produce more people (male and female) with diabetes (Table 4.15, Table 4.16).

Table 4.15: Number of males with diabetes, comparison between 2005 age adjusted rates to 2035 population structure age adjusted with 2005 population

	2005	2005 (2035 pop. Struc)	2015	2015 (2035 pop. Struc)	2025	2025 (2035 pop. Struc)	2035	2035 (2035 pop. Struc)
1-4	62	54	121	107	141	124	142	125
5-9	164	142	286	248	363	315	386	335
10-14	298	247	420	348	519	430	573	475
15-19	449	368	599	492	720	591	798	655
20-24	583	490	770	648	980	824	1037	872
25-29	780	685	1188	1044	1536	1349	1595	1402
30-34	1254	1072	1962	1676	2558	2185	2794	2387
35-39	2038	1789	3472	3048	4357	3824	4925	4323
40-44	3477	2819	6102	4948	7541	6115	8526	6913
45-49	5381	4460	9083	7529	11049	9158	11892	9857
50-54	7305	6987	10690	10225	13802	13202	14369	13744
55-59	8850	9611	11742	12752	16232	17627	16722	18160
60-64	8740	12267	11513	16159	14474	20314	16409	23030
65-69	8176	13536	11080	18344	13272	21973	16265	26928
70-74	7470	14631	11401	22330	13103	25663	14398	28199
75-79	5893	12861	9280	20254	10744	23449	11056	24131
80-84	3579	8128	5176	11754	7084	16087	6885	15635
85+	1959	4425	2831	6395	4030	9103	4268	9641
Total	66459	94574	97718	138298	122503	172331	133043	186811

Table 4.16: Number of females with diabetes, comparison between 2005 age adjusted rates to 2035 population structure age adjusted with 2005 population

	2005	2005 (2035 pop. Struc)	2015	2015 (2035 pop. Struc)	2025	2025 (2035 pop. Struc)	2035	2035 (2035 pop. Struc)
1-4	42	36	75	66	87	76	88	76
5-9	146	126	201	173	244	209	258	222
10-14	330	271	360	295	417	342	452	370
15-19	451	367	569	463	638	520	684	557
20-24	667	551	792	655	918	760	945	782
25-29	1080	938	1216	1056	1409	1224	1430	1242
30-34	2005	1737	2238	1939	2573	2229	2716	2353
35-39	3273	2849	3664	3190	4064	3538	4473	3894
40-44	4763	3777	6098	4836	6580	5218	7215	5722
45-49	5798	4843	8222	6868	9068	7574	9393	7846
50-54	6318	6179	9098	8899	11496	11244	11416	11165
55-59	6784	7372	10123	11001	13931	15139	14051	15269
60-64	6500	8981	9562	13213	11916	16465	13899	19206
65-69	6194	10107	9005	14693	11031	17997	13664	22295
70-74	6341	12394	9710	18980	11509	22496	12489	24412
75-79	5695	11344	8841	17610	10545	21005	11092	22095
80-84	4237	7600	6181	11086	8621	15462	8719	15638
85+	3219	5401	4522	7587	6630	11123	7431	12467
Total	63843	84874	90477	122608	111676	152620	120415	165610

4.6 Sensitivity Analyses

4.6.1 Scenario 0: base model with assumptions of a 10 year increase in incidence rates and a 10 year decrease in mortality rates based on trends seen in ADSS data.

4.6.2 Scenario 1: constant 2005 diabetes incidence and mortality rates (2006–2035).

Diabetes incidence and mortality rates were held at a constant 2005 level for the duration of the model (2006 to 2035). From the projection model, the overall prevalence of diabetes will increase from 4.00% in 2005 to 7.52% in 2035 in females and from 4.18% in 2005 to 8.22% in 2035, in males, (Table 4.17; Table 4.20). Holding the incidence and mortality rates at 2005 levels, the overall diabetes prevalence rates were forecasted to be substantially lower than the base case (Scenario 0), 10.39% and 10.77% for females and males, respectively (Table 4.17; Table 4.20). Age specific diabetes prevalence rates increased to a maximum of 20% in the 75–79 age band over as little as 10 years, followed by a leveling off around an age specific prevalence rate of about 20% (not shown). The total costs are expected to be reduced from 1081 million dollars in the base model to 785 million dollars in females, and from 1216 million dollars in the base model to 869 million dollars in males, resulting in a 296 and 347 million dollar decrease in total costs for females and males, respectively (Table 4.18; Table 4.21). The decrease in total costs is attributable to a decrease in the number of people with diabetes; that is, 66221 and 82217 fewer cases compared to the base model in females and males, respectively (Table 4.19; Table 4.22)

4.6.3 Scenario 2: a 10% increase in the rate of diabetes incidence change.

The rate of diabetes incidence change was increased by 10% for all age groups for the duration (2006–2015) of the base model (Scenario 0). A 10% increase results in an overall diabetes prevalence increase from 10.4% in the base model to 10.6% in 2035 from 2005, and from 11.8% to 12.0% in females and males, respectively (Table 4.17; Table 4.20). The total cost is observed to be higher from 1081 million dollars in the base model to 1104 million dollars in females, and from 1216 to 1243 million dollars in males, resulting in a 24 and 27 million dollar increase in total costs for females and males,

respectively (Table 4.18; Table 4.21). The increase in total costs is attributable to an increase in the number of people with diabetes; that is, 5248 and 6274 additional cases compared to the base model in females and males, respectively (Table 4.19; Table 4.22).

4.6.4: Scenario 3: a 10% decrease in the rate of diabetes incidence change.

The rate of diabetes incidence change was decreased by 10% for all age groups for the duration (2006–2015) of the base model (Scenario 0). A 10% decrease results in an overall diabetes prevalence decrease from 10.4% in the base model to 10.2% and from 11.8% in the base model to 11.5% in 2035 from 2005 in females and males respectively (Table 4.17; Table 4.20). The total cost is predicted to be lower by 24 and 27 million dollars compared to the base model in 2035 and results in 5290 and 6331 fewer in females and males, respectively, with diabetes compared to the base model (Table 4.18; Table 4.19; Table 4.21; Table 4.22).

4.6.5 Scenario 4: non diabetic mortality slopes.

Currently, diabetes mortality rates are higher and decreasing at a faster rate than non diabetic mortality rates (Figure 3.4). To remove the effects of a lower mortality rate each year in the diabetic population, the model forecasts the effects of higher mortality rates by incorporating non diabetic mortality slopes into the model. The model forecasts that the overall diabetes prevalence will be lower than the base model from 10.4% in the base model to 10.0% and 11.8% in the base model to 11.4% in 2035 in females and males, respectively (Table 4.17: Table 4.20). Total costs are expected to be 33 and 24 million dollars lower in females and males, respectively, compared to the base case (Scenario 0) (Table 4.18; Table 4.21). The lower diabetes prevalence will also result in 8546 and 7345 fewer cases of diabetes in females and males, respectively (Table 4.19; Table 4.22).

4.6.6 Scenario 5: a 5 year change in diabetes incidence and mortality.

The duration of diabetes incidence and mortality effects was varied by modifying the duration of incidence and mortality change from 10 years (Scenario 0) to 5 years. The overall diabetes prevalence is lower from 10.4% in the base model compared to 9.0% and 11.8% compared to 10.0% in 2035, in females and males, respectively (Table 4.17; Table

4.20). Total costs were observed to be 144 and 168 million dollars lower compared to the base case in females and males, respectively (Table 4.18; Table 4.21). The shorter duration of diabetes prevalence resulted in 32542 and 40495 fewer cases of diabetes in females and males, respectively (Table 4.19; Table 4.22).

4.6.7 Scenario 6: a 15 year change in diabetes incidence and mortality.

The duration of diabetes incidence and mortality change was modified from 10 years (Scenario 0) to 15 years. With a 15 year duration in diabetes incidence and mortality rate changes the overall diabetes prevalence is higher from 10.4% in the base model compared to 11.7% and 11.8% compared to 13.4% in 2035, in females and males, respectively (Table 4.17: Table 4.20). Total costs are expected to be 129 and 151 million dollars higher compared to the base case in females and males, respectively (Table 4.18; Table 4.21). The higher diabetes prevalence will result in 30225 and 37777 more cases of diabetes in females and males, respectively (Table 4.19; Table 4.22).

4.6.8 Scenario 7: diabetes incidence growth for 15 years and a 5 year duration of diabetes mortality decrease.

To model the effects of a longer incidence increase and a shorter mortality decrease, diabetes incidence and mortality rates were varied. Incidence rates were assumed to increase for a duration of 15 years, while mortality rates were assumed to decrease for a duration of 10 years. From the analysis, overall diabetes prevalence is expected to be higher from 10.4% in the base model compared to 11.0% and 11.8% compared to 12.5% in 2035, in females and males, respectively (Table 4.17: Table 4.20). Total costs are expected to be 71 and 73 million dollars higher in females and males, respectively (Table 4.18; Table 4.21). The higher diabetes prevalence rates caused by longer incidence effects and higher mortality rates will result in 14739 and 15867 more cases of diabetes in 2035 in females and males, respectively (Table 4.19; Table 4.22).

4.6.9 Scenario 8: diabetes incidence growth for 5 years and a 15 year duration of diabetes mortality decrease

To model the effects of a shorter incidence increase and a longer mortality decrease, diabetes incidence rates were assumed to increase for a duration of 5 years and diabetes mortality rates were assumed to decrease for a duration of 15 years. This scenario assumes a healthier Alberta population with fewer people progressing to the diabetes state and more people living longer, as reflected in the lower mortality rates. The model predicts that overall diabetes prevalence is expected to be lower from 10.4% in the base model compared to 9.6% and 11.8% compare to 10.9% in 2035, in females and males, respectively (Table 4.17: Table 4.20). Total costs are expected to be 91 and 97 million dollars lower than the base case in females and males, respectively (Table 4.18; Table 4.21). The decrease in prevalence rates translates to 19164 and 21309 fewer cases of diabetes in 2035 in females and males, respectively (Table 4.19; Table 4.22).

Table 4.17: Sensitivity analyses: female projected prevalence rates for all age bands for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
1-4	0.05%	0.11%	0.07%	0.12%	0.11%	0.11%	0.09%	0.13%	0.13%	0.09%
5-9	0.15%	0.26%	0.17%	0.26%	0.25%	0.26%	0.22%	0.30%	0.30%	0.22%
10-14	0.30%	0.41%	0.29%	0.42%	0.40%	0.41%	0.35%	0.47%	0.47%	0.35%
15-19	0.39%	0.59%	0.43%	0.61%	0.58%	0.59%	0.52%	0.66%	0.66%	0.52%
20-24	0.56%	0.80%	0.66%	0.81%	0.78%	0.80%	0.73%	0.85%	0.85%	0.73%
25-29	0.93%	1.23%	1.12%	1.24%	1.22%	1.23%	1.18%	1.27%	1.27%	1.18%
30-34	1.74%	2.36%	2.11%	2.38%	2.33%	2.36%	2.24%	2.46%	2.46%	2.24%
35-39	2.78%	3.79%	3.15%	3.86%	3.73%	3.79%	3.48%	4.09%	4.09%	3.48%
40-44	3.47%	5.25%	4.19%	5.36%	5.15%	5.25%	4.73%	5.74%	5.74%	4.73%
45-49	4.34%	7.03%	5.52%	7.18%	6.88%	7.03%	6.30%	7.71%	7.71%	6.30%
50-54	5.73%	10.35%	7.92%	10.59%	10.11%	10.35%	9.17%	11.43%	11.43%	9.17%
55-59	7.63%	15.81%	11.64%	16.19%	15.43%	15.50%	13.77%	17.70%	17.26%	14.14%
60-64	10.23%	21.87%	15.94%	22.38%	21.37%	21.18%	18.97%	24.54%	23.58%	19.78%
65-69	12.27%	27.06%	19.89%	27.65%	26.46%	26.38%	23.58%	30.19%	28.96%	24.64%
70-74	14.33%	28.23%	20.18%	28.86%	27.59%	27.25%	24.31%	31.80%	29.96%	25.89%
75-79	15.11%	29.43%	20.28%	30.10%	28.77%	27.79%	24.93%	33.63%	30.77%	27.39%
80-84	14.63%	30.11%	20.23%	30.76%	29.45%	28.20%	25.20%	34.76%	30.84%	28.60%
85+	11.85%	27.35%	17.12%	27.92%	26.78%	24.36%	22.12%	32.57%	26.76%	27.21%
Total	4.00%	10.39%	7.52%	10.62%	10.16%	10.02%	8.98%	11.70%	11.03%	9.56%

Table 4.18: Sensitivity analyses: female total health care costs and percentage increases by type of co-morbidity from 2005 for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
CV costs	66	304	219	311	297	294	263	341	324	279
Renal costs	18	65	49	66	63	64	57	71	70	58
Ophthalmic	6	29	20	29	28	27	24	32	30	27
Other	165	683	496	698	668	662	592	765	727	626
Total	255	1081	785	1104	1057	1048	937	1210	1151	990
% change from 2005		324%	208%	333%	314%	311%	268%	374%	351%	288%

Table 4.19: Sensitivity Analyses: number of females with diabetes and percentage increase from 2005 for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
Total	63843	239734	173513	244981	234444	231188	207192	269958	254472	220570
Difference from 2005	-	175890	109669	181138	170601	167345	143349	206115	190629	156727
Difference from Scenario 0	-	-	-66221	5248	-5290	-8546	-32542	30225	14739	-19164
% increase from 2005	-	276%	172%	284%	267%	262%	225%	323%	299%	245%

Table 4.20: Sensitivity analyses: Male projected prevalence rates for all age bands for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
1-4	0.08%	0.17%	0.11%	0.18%	0.17%	0.17%	0.14%	0.21%	0.21%	0.14%
5-9	0.15%	0.36%	0.23%	0.38%	0.35%	0.36%	0.30%	0.43%	0.43%	0.30%
10-14	0.26%	0.49%	0.36%	0.51%	0.48%	0.49%	0.43%	0.55%	0.55%	0.43%
15-19	0.37%	0.66%	0.49%	0.67%	0.64%	0.66%	0.58%	0.73%	0.73%	0.58%
20-24	0.49%	0.87%	0.64%	0.89%	0.84%	0.87%	0.76%	0.96%	0.96%	0.76%
25-29	0.67%	1.38%	1.01%	1.41%	1.34%	1.38%	1.20%	1.54%	1.54%	1.20%
30-34	1.08%	2.40%	1.65%	2.48%	2.33%	2.40%	2.04%	2.74%	2.74%	2.04%
35-39	1.74%	4.21%	2.82%	4.35%	4.07%	4.21%	3.53%	4.84%	4.84%	3.53%
40-44	2.58%	6.32%	4.31%	6.52%	6.12%	6.32%	5.34%	7.21%	7.21%	5.34%
45-49	3.95%	8.72%	6.22%	8.97%	8.48%	8.72%	7.52%	9.81%	9.81%	7.52%
50-54	6.39%	12.58%	9.26%	12.90%	12.25%	12.58%	10.98%	13.99%	13.99%	10.98%
55-59	9.76%	18.44%	13.53%	18.88%	17.99%	18.19%	16.07%	20.56%	20.14%	16.42%
60-64	13.67%	25.66%	18.32%	26.26%	25.06%	24.71%	22.08%	28.97%	27.51%	23.31%
65-69	16.69%	33.20%	23.30%	33.93%	32.46%	31.52%	28.32%	37.78%	34.87%	30.81%
70-74	18.13%	34.95%	24.13%	35.67%	34.21%	33.18%	29.56%	40.08%	35.94%	33.16%
75-79	18.86%	35.38%	24.10%	36.10%	34.66%	33.87%	29.75%	40.74%	35.98%	33.96%
80-84	18.69%	35.95%	24.08%	36.65%	35.24%	35.22%	30.00%	41.62%	35.96%	35.06%
85+	15.62%	34.02%	21.78%	34.67%	33.36%	34.71%	27.85%	39.95%	33.27%	33.91%
Total	4.18%	11.77%	8.22%	12.04%	11.50%	11.45%	10.02%	13.40%	12.46%	10.85%

Table 4.21: Sensitivity analyses: male total health care costs and percentage increases by type of co-morbidity from 2005 for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
CV costs	72	341	243	348	333	332	293	384	359	316
Renal costs	20	78	57	80	76	77	68	86	85	70
Ophthalmic	6	31	22	32	31	30	27	36	33	29
Other	173	766	547	783	749	752	660	861	813	704
Total	271	1216	869	1243	1189	1192	1048	1367	1289	1119
% change from 2005	349%	221%	359%	339%	340%	287%	405%	376%	313%	

Table 4.22: Sensitivity Analyses: number of males with diabetes and percentage increase from 2005 for various scenarios

	2005	Scenario 0 (2035)	Scenario 1 (2035)	Scenario 2 (2035)	Scenario 3 (2035)	Scenario 4 (2035)	Scenario 5 (2035)	Scenario 6 (2035)	Scenario 7 (2035)	Scenario 8 (2035)
Total	66459	272312	190095	278586	265982	264967	231817	310090	288180	251003
Difference from 2005	-	205853	123636	212127	199522	198508	165358	243630	221720	184544
Difference from base model	-	-	-82217	6274	-6331	-7345	-40495	37777	15867	-21309
% increase from 2005	-	310%	186%	319%	300%	299%	249%	367%	334%	278%

Female Sensitivity Analysis

Figure 4.12: Prevalence of diabetes mellitus for females under various sensitivity analyses scenarios..

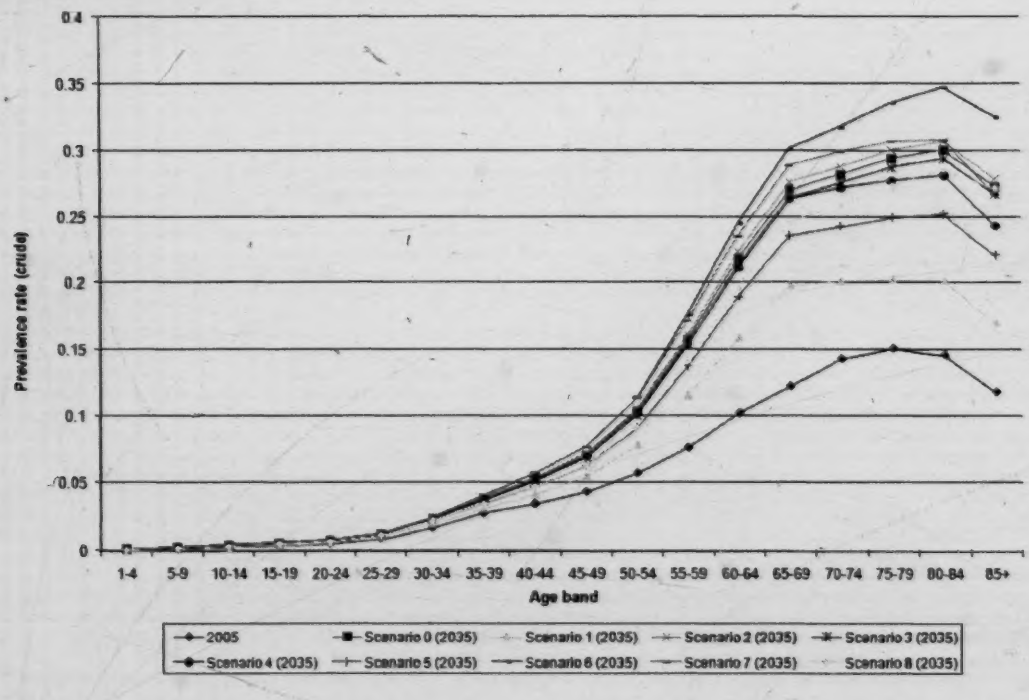
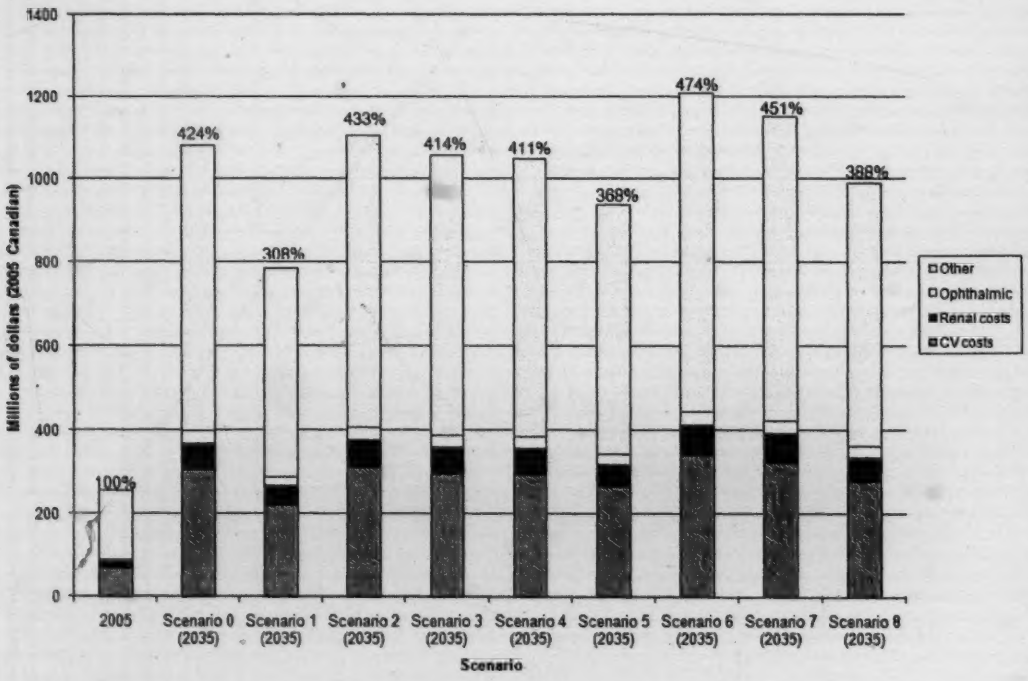
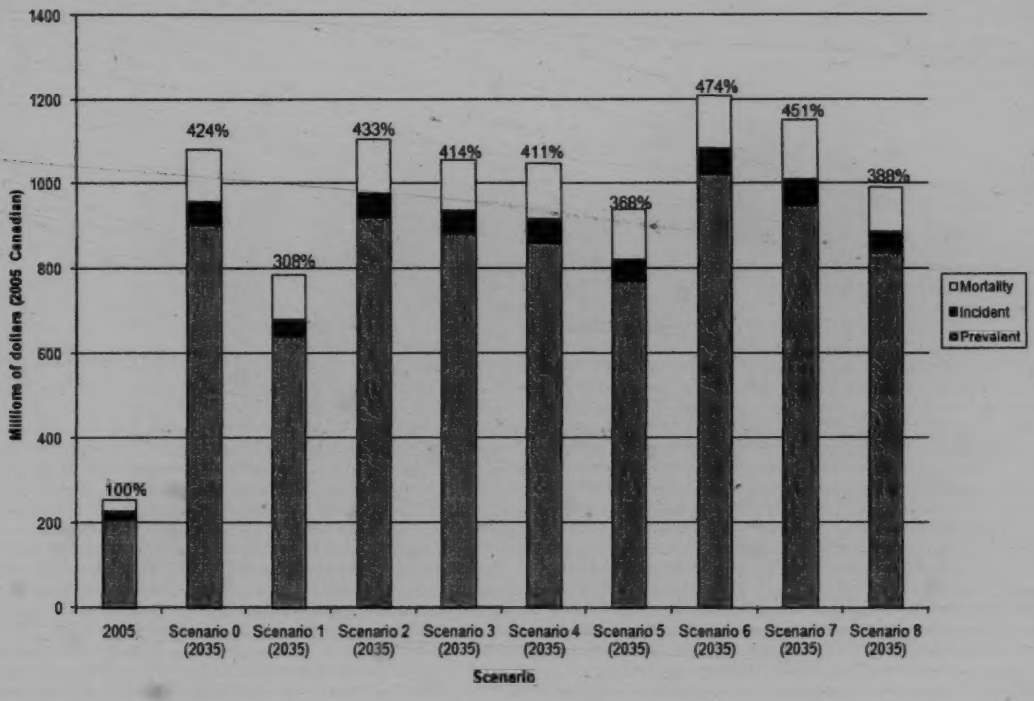


Figure 4.13: Total health care costs by type of co morbidity for females for various scenarios.



Percentage = percentage growth in relation to 2005 health care costs

Figure 4.14: Total health care costs by case type for females for various scenarios.



Percentage = percentage growth in relation to 2005 health care costs

Male Sensitivity Analysis

Figure 4.15: Prevalence of diabetes mellitus for males under various sensitivity analyses scenarios.

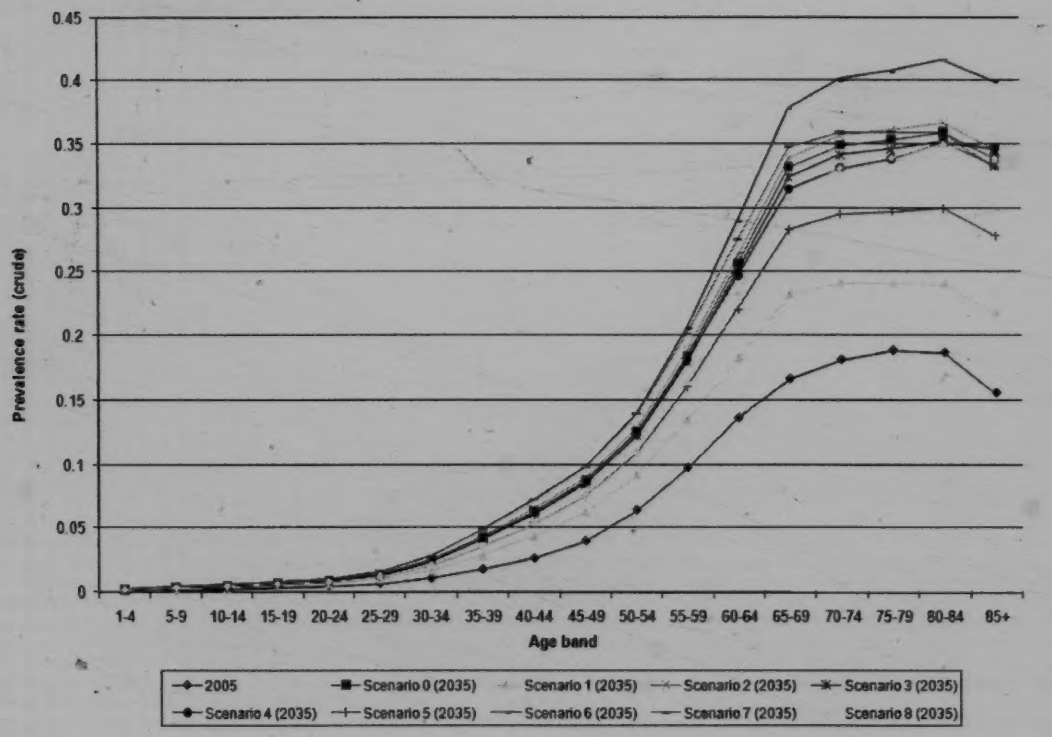
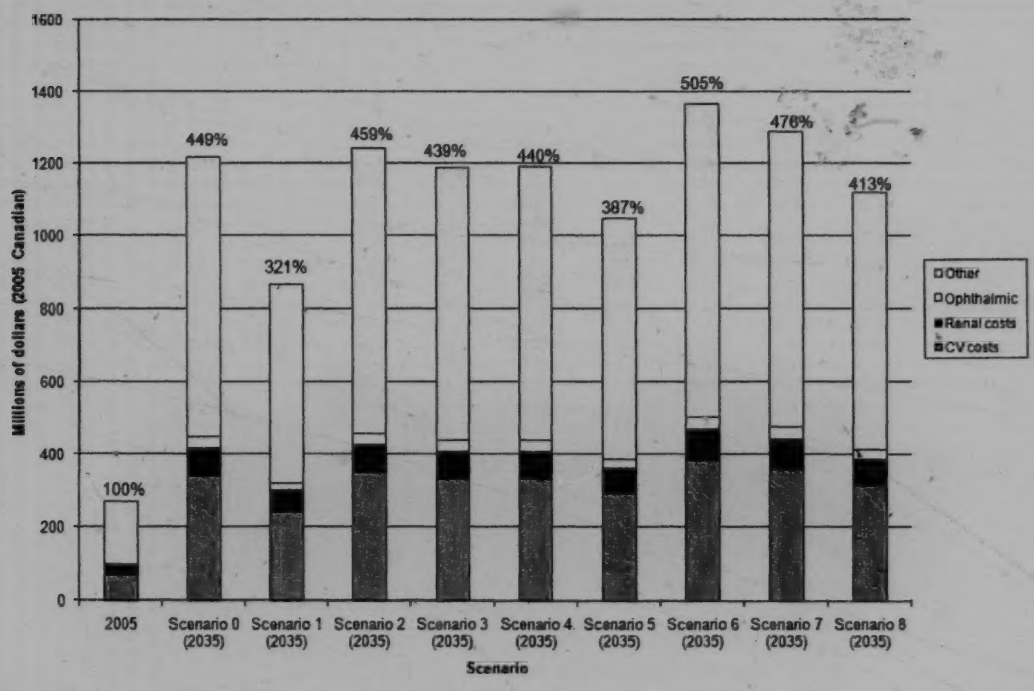
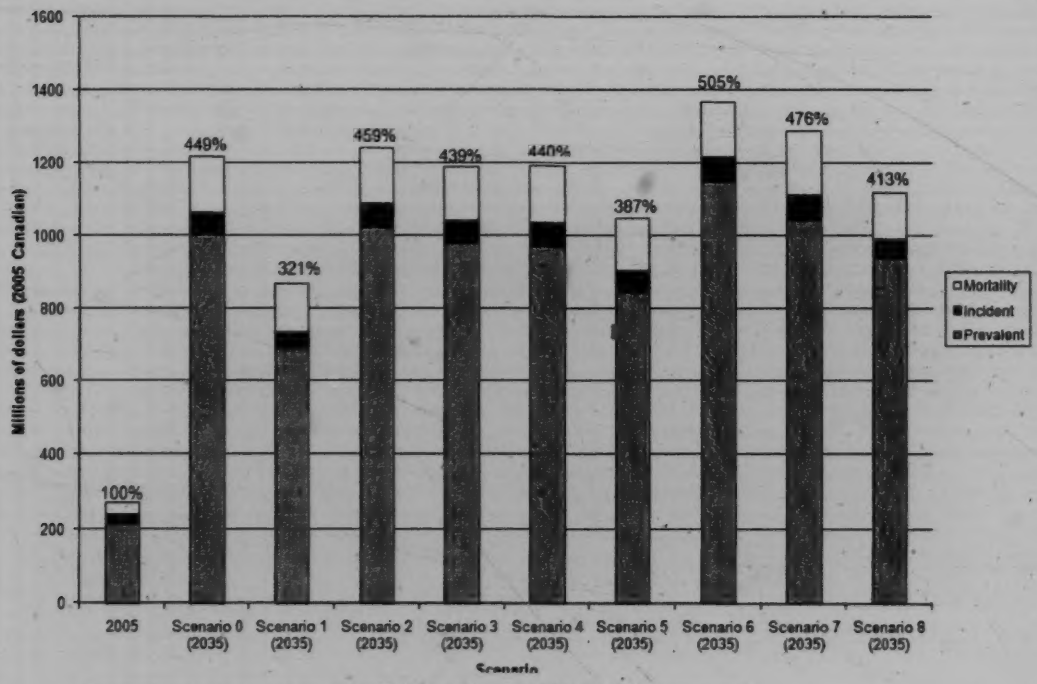


Figure 4.16: Total health care costs for various scenarios for males.



Percentage = percentage growth in relation to 2005 health care costs

Figure 4.17: Sensitivity analysis: total health care costs by case type for males for various scenarios.



Percentage = percentage growth in relation to 2005 health care costs

5.0 Discussion

5.1 Alberta Diabetes Projection Model inputs

The Alberta Diabetes Projection Model is based on actual observed inputs, the trends observed in the province over the previous 10-year period, which are consistent with trends seen in provinces across Canada (Johnson and Vermeulen, 2007; Lipscombe and Hux, 2007). Observational studies on diabetes trends in Alberta (Johnson and Vermeulen, 2007) and Ontario (Lipscombe and Hux, 2007) have shown that diabetes incidence and mortality have been increasing and decreasing, respectively. Studies by Thomas et al. (2003) and Stovring et al. (2003) have shown that mortality rates have been steadily declining in people with diabetes; if this trend is not included when researching future trends of diabetes, incorrect conclusions may be made about the growing number of people with diabetes. These trends, along with increasing obesity rates (Karzmarzyk 2006; Lau 2007, Hopman 2007), have been contributing to the increasing prevalence of diabetes seen in Alberta and Ontario. By combining increasing incidence rates and decreasing mortality rates, the Alberta Diabetes Projection Model can forecast the future burden of diabetes with confidence. Based on trends seen in the ADSS data (1995-2005), incidence and mortality rates of diabetes were predicted to continue the observed trends for an additional 10 years. From 2005 to 2015, incidence was projected to increase by 32% and 39% in females and males, respectively, while population growth was observed to be 18% and 19% in females and males respectively. For the same time period, mortality rates were predicted to decrease by 26% from 2005 to 2015 in both females and males.

5.2 Prevalence rates in Alberta

The Alberta Diabetes Projection Model predicts that crude prevalence rates will increase from 4.0% in 2005 to 10.4% in 2035 in females and from 4.2% in 2005 to 11.8% in 2035 in males; these represent 160% and 181% increases in females and males, respectively. These crude rates incorporate the changing population demographics, where in 2005 a majority of the population was found in the < 50 years of age, while in 2035 the population structure has been predicted to be almost evenly distributed (Figure 5). In order to isolate the effects of the shifting population structure on the prevalence rates, age

standardized rates were calculated and compared to crude rates. The reference population was calculated by summing of each year's population (2005-2035). The Alberta Diabetes Projection Model predicts 94% and 100% increase in age adjusted prevalence rates in females and males, respectively. The changing population structure is predicted to reallocate individuals with diabetes from younger age groups (< 55 years of age) to older age groups (≥ 55 years of age). Combined with the high incidence rates of diabetes in older age bands, this results in higher prevalence rates.

The pattern of growth in prevalence rates is consistent with trends seen in Alberta (Johnson and Vermeulen, 2007), Ontario (Lipscombe and Hux, 2007), Manitoba (Blanchard et al., 1996), and the United States (Mokdad et al., 2000). Lipscombe and Hux (2007) report that age and sex adjusted prevalence rates have increased by 68.6% from 1995 to 2005, with an age and sex adjusted incidence rate increase of 30.7% from 1997 to 2003. Prevalence was observed to grow linearly with an average yearly growth of 6.2%. Johnson and Vermeulen (2007) have shown that age adjusted diabetes prevalence in Alberta has increased by 52% from 1995 to 2005, with a male age adjusted rate increase of 43.9% and a female age adjusted rate increase of 37.6% from 1995 to 2005. Blanchard et al. (1996) report that age adjusted prevalence rates have increased from 47.1 per 1000 in 1986 to 69.7 per 1000 in 1991, a 48% prevalence increase. Mokdad et al. (2000) observed age and sex adjusted prevalence trends to increase from 4.9% in 1990 to 5.9% in 1998, a 20% increase in prevalence rates.

The Alberta Diabetes Projection Model predicts that in 2015, 2025, and 2035 the largest number of people with diabetes will be in the 60–64, 65–69, and 70–74 age bands, with the largest prevalence rates in the 75–79, 80–84, and 80–84 age bands, respectively. The largest number of people with diabetes in the 55–59 age band observed by Johnson and Vermeulen (2007) will steadily age and progress through the model. This poses problems for the health care system as it will now have to face an older aging population that has diabetes; it will be difficult to justify medical interventions for an older age group if costs outweigh benefits.

The Alberta Diabetes Projection Model prevalence rate estimates are larger compared to previously published forecasting models in Canada (Ohinmaa et al., 2004), globally (Wild et al., 2004; King et al., 1998) and the United States (Boyle et al., 2001;

Honeycutt et al., 2003). Ohinmaa et al. (2004) projected the number of people having diabetes to grow from 1.4 million in 2000 to 2.4 million in 2016, a 75% increase over 15 years, while population growth was expected to increase by approximately 12%. The largest increase in the number of people with diabetes was expected to be highest in Alberta with an 85.8% change in 2016 from 2000, followed by British Colombia, Ontario and the territories. Diabetes prevalence rates were found to be the highest in the age group of 55 to 60 years of age and in the greater than 80 years of age. This increase in diabetes prevalence is a result of an aging population. The Alberta Diabetes Projection Model from 2005 to 2020 projects the number of people with diabetes to increase from 130,000 in 2005 to 327,000 in 2020, a 151% increase over 15 years.

The WHO predicts that the global burden of diabetes for all age groups will reach 4.4% by 2030 from 2.8% in 2000 (Wild et al., 2004), which equates to 171 million people with diabetes in 2000 and 366 million people with diabetes in 2030, with a prevalence rate of growth of 57% and a 114% increase in the number of people with diabetes from 2000 to 2030. The recent report from Ontario suggests that the WHO predictions for diabetes prevalence in Canada for 2030 have already been exceeded (Lipscombe and Hux 2007). Prevalence predictions of Ohinmaa et al. (2004) are also higher than predictions made by the WHO.

King et al. (1998) predicted that the global prevalence of diabetes will increase from 4.0% in 1995 to 5.4% in 2025 in the population over 20 years of age, an increase from 135 million people with diabetes in 1995 to 300 million people with diabetes in 2025, a 122% increase. The WHO predicts that in Canada, the number of people with diabetes will increase from 2 million in 2000 to 3.5 million by 2030 (World Health Organization, 2008), a 75% increase.

The Alberta projections are expected to be higher than global projections. Global diabetes prevalence rates were observed and forecasted to be higher in developed countries; however, developing countries have larger increases in prevalence rates (King et al., 1998). King et al. (1998) projected that developing countries will experience a 170% increase in the number of people with diabetes, from 84 million in 2000 to 228 million in 2025 compared to a 42% increase in the number of people with diabetes in developed countries, from 51 million in 2000 to 72 million in 2025. Higher forecasted

prevalence rates in Alberta compared to global standards is consistent with the literature. The lifestyles in developed countries contribute to high obesity rates and non-communicable diseases, as residents commonly consume products with high levels of saturated fats which are expensive or unavailable in the developing world. Developed countries are obesogenic environments consisting of numerous fast food outlets, vending machines, and pop machines (Chopra et al., 2002). Currently developing nations that are experiencing rapid rates of urbanization have concomitant increases in obesity and non-communicable diseases linked to environment and lifestyle changes.

The Alberta prediction on diabetes prevalence is greater than predicted prevalence rates in the United States. Boyle et al. (2001) predict that the number of Americans with diagnosed diabetes will increase from 11 million in 2000 to 29 million in 2050, a 165% increase. Honeycutt et al. (2003) predict the number of Americans diagnosed with diabetes will increase from 12 million in 2000 to 39 million in 2050, with a prevalence rate of 4.4% in 2000 and 9.7% in 2050, a 225% increase in the number of individuals with diagnosed diabetes. An updated projection by Narayan et al. (2006) predicted that prevalence in the United States will increase from 16.2 million in 2005 to 48.3 million in 2050, a 198% increase. According to Alberta projections, the number of people with diabetes in Alberta will increase by 294% over 30 years (2005–2035) compared to a 198% (Narayan et al., 2006) and a 225% (Honeycutt et al., 2003) increase in the U.S. over 50 years. The burden of diabetes in the future is likely to be much greater than previously predicted (Lipscombe and Hux, 2007).

Differences in prevalence projections are due to differences in methodology and assumptions regarding input trends. The predictions by King et al. (1998), assumed baseline age and sex specific prevalence rates to be constant while Boyle et al. (2001), Wild et al. (2004) extrapolated prevalence estimates obtained from surveys or from literature and applied these estimates to projections of their corresponding populations (U.S. Census Bureau [Boyle et al., 2001]; UN population estimates [Wild et al., 2003]; King et al., 1998). Studies also differ in projected segments of their populations. Wild et al. (2004) and King et al. (1998) both project the prevalence of diabetes in individuals over the age of 20, and Boyle et al. (2001) project the prevalence of diabetes in the entire population. And finally, the different models used different statistical techniques to arrive

at projected burden of diabetes. Honeycutt et al. (2003) and Narayan et al. (2006) used a Markov model to project the future burden of diabetes which used better quality inputs such as incidence rates, prevalence rates, and mortality rates to predict the future trends of diabetes. The input data was obtained from the U.S. Census Bureau and the National Health Interview Survey (NHIS) for all age groups. Future diabetes incidence and prevalence rates were logistically regressed from NHIS data (1984–2000).

The Alberta Diabetes Projection Model utilizes the most recent incidence, prevalence, and mortality data, thus we expect it to provide a good prediction of the future burden of diabetes. Although the Alberta Diabetes Projection Model forecasts prevalence rates to be higher than previously predicted (King et al., 1998; Wilde et al., 2004; Honeycutt et al., 2003; Narayan et al., 2006; Boyle et al., 2001), the Alberta projections are still a conservative estimate of the future burden of diabetes and underestimate the true burden of diabetes in Alberta: 1) the Alberta Diabetes Projection Model does not capture undiagnosed diabetes mellitus and 2) the 10 year duration of trends followed by a abrupt stop in trends may underestimate the actual trend of diabetes prevalence in Alberta.

5.3 Cost projections for Alberta

In addition to projecting future burden of diabetes in terms of epidemiologic trends, the Alberta Diabetes Projection Model predicts future health care costs for the population living with diabetes. As would be expected, total costs for both females and males with diabetes were forecasted to rise. In females, total costs rose by 88%, 213%, and 324% in 2015, 2025, and 2035 above the estimated 2005 levels; the total cost of health care accrued to females with diabetes is $479, $795, and $1081 million in health care costs for both diabetes related and diabetes unrelated costs. The largest increase in costs was found to be in ophthalmic services, a 368% increase from 2005 levels. Costs of "other" complications, including amputations, and all diabetes related and unrelated costs contributed the most to the total, at 63%, followed by cardiovascular (CV) costs at 28%. Cost for those cases who died in each year showed the largest growth—353% from 2005 to 2035, followed by prevalence cases—338% from 2005 to 2035. However, prevalent

cases make up the largest proportion of total costs spent on diabetes care and treatment, at 83% in 2035.

In males, total costs are predicted to rise by 98%, 233%, and 349% in 2015, 2025, and 2035 from 2005 levels; the total cost of health care accrued to males with diabetes is $536, $903, and $1216 million in health care costs for both diabetes related and unrelated costs. The largest increases in costs were found in ophthalmic services, a 395% increase in 2035 from 2005 levels. "Other" complications contributed the most to total costs, followed by cardiovascular costs, 63% and 28%, respectively in 2035. In males, growth in total costs were similar for prevalent cases and cases who died in each year at 369% and 366%, respectively. Prevalent cases contribute the largest proportion to total costs spent on diabetes care and treatment, 82% in 2035.

Estimated increases in health care costs from the Alberta Diabetes Projection Model are larger than previous cost projections in Canada and the United States. Ohinmaa et al. (2004) projected costs of diabetes in Canada to increase from $4.66 billion in 2000 to $8.14 billion in 2016 (1996 Canadian dollar values), a 75% increase in total health care costs over 16 years, while the Alberta Diabetes Projection Model predicts a 93% increase in total costs in as little as 10 years (2005–2015). The Canadian Diabetes Association (2006) estimates diabetes currently costs the Canadian economy $13.2 billion a year and by 2020 the cost of diabetes will be $19.2 billion per year, a 45% increase.

In the United States, cost studies by the American Diabetes Association (ADA) found that direct medical costs in 2007 in the United States totaled 116 billion dollars: 27 billion to treat diabetes, 58 billion to treat diabetes related complications, and 31 billion in excess general medical costs (ADA, 2008). Between 2002 and 2007, direct medical expenditures from diabetes grew by 26% in the United States (ADA, 2003; 2008). From the Alberta Diabetes Projection Model, health care costs over 5 years (2005–2010) will increase by 39% if the status quo remains.

Differences in cost estimate are also due to differences in model assumptions and costing methodology. For example, the Alberta Diabetes Projection Model assumes incidence rates increase linearly and mortality rates decrease linearly over a ten year duration. The number of incidence and prevalent cases and deaths were multiplied by

Saskatchewan health care cost data (CPI adjusted) separated and organized by type of co-morbidity and case type. The Saskatchewan cost data was obtained by identifying a diabetic individual and the costs that were accrued by following their resources consumption through linkable health care databases (Ohinmaa et al., 2004). The Alberta Diabetes Projection Model uses the same cost data in the Ohinmaa et al. (2004) study, however, Ohinmaa et al. (2004) modeled an increase in mortality rates over time. The model assumption of mortality rates increasing over time, would lead to an overestimated number of deaths, and untimely removal of prevalent diabetic individuals out of the population. This may result in an underestimation of the predicted future cost increases.

The ADA used a different approach to calculate their annual estimate of the costs of diabetes, compiling cost estimates from various sources and *attributing* a portion to diabetes (ADA 2008). The ADA estimates have included both direct and indirect costs, providing an overall estimate of the total economic burden of diabetes (ADA 2008). The most recent estimate from ADA suggests the direct costs of care are twice the indirect costs (ADA 2008). For the direct cost portion, rather than calculating actual costs accrued by individuals with diabetes from linkable administrative data bases, resource use attributable to diabetes was calculated by comparing health care use attributable to individuals with diabetes and individuals without diabetes. Health resource utilization data for patients was obtained from a variety of data bases and include 1) national health care surveys (National Centre for Health Statistics [NCHS], 2) Hospital Discharge Survey, 3) National Nursing Home Survey, 4) National Ambulatory Medical Care Survey [NHAMCS], 5) National Survey of Ambulatory Surgery, 6) IMS America, etc.). Medical expense attributable to diabetes was calculated by multiplying mean expenditures per encounter by the diabetic individuals' health resource utilization.

Using numerous data sources has its disadvantages, however, such as differences and inconsistency in costing methodology. This inconsistency may result in large discrepancies in the true cost of diabetes. The Alberta projections and the study by Ohinmaa et al. (2004), uses Saskatchewan Health cost data which was obtained from persons identified with diabetes within linkable administrative databases rather than determining health care resource consumption through comparisons of resources use between individuals with diabetes and individuals without diabetes.

The Alberta Diabetes Projection Model is a robust model that predicts prevalence and costs due to diabetes. The incidence, prevalent and mortality data are obtained from Alberta Health and Wellness, analyzed by the team at Alliance for Canadian Health Outcomes Research in Diabetes (ACHORD), and organized into the Alberta Diabetes Atlas where the data were obtained for the Alberta Diabetes Projection Model. In this current version of the projection model the cost data were derived from Saskatchewan Health 1996 and inflated to 2005 Canadian dollars using the Bank of Canada CPI (Bank of Canada, 2007); the Alberta Diabetes Projection Model will be updated with Alberta specific diabetes utilization and cost data from Alberta Health and Wellness as soon as they become available.

In addition to direct medical costs, indirect costs (loss of economic activity due to illness) and intangible costs (social and personal privation) are associated with diabetes and its related illnesses. In 1998 the total economic burden of diabetes in Canada was found to be between $4.76 and $5.23 billion with direct medical costs of diagnosed and undiagnosed diabetes equal to 3.5 billion and indirect costs of diagnosed and undiagnosed diabetes equal to $1.3 billion (Dawson et al., 2002). These estimates do not include social and personal losses (intangible costs) associated with diabetes, thus they underestimate the true economic cost of diabetes. In 2007, the economic cost of diagnosed diabetes in the United States was found to be $174 billion (USD), with $116 billion (USD) in excess medical expenditures and $58 billion (USD) in foregone productivity (American Diabetes Association, 2008). Studies from Canada and the United States, agree that the economic cost of diabetes is large and increasing at a rapid rate; however, the estimates made in these studies do not include social and personal losses associated with diabetes and its related illnesses and therefore underestimate the true cost of this disease. Personal costs entail having to inject insulin, take drugs, and monitor blood sugar levels, while social costs include the increased burden of diabetes on friends and family members.

The Alberta Diabetes Projection Model shows that direct medical costs of treating people with diabetes, including related and unrelated medical costs, will increase by over 337% by 2035; this is still a gross underestimate as it does not include indirect medical

costs, productivity losses and intangible costs. When these costs are included, the total economic cost of diabetes in Alberta would likely be larger than $2 billion in 2035.

5.4 Limitations of the Alberta Diabetes Projection Model

An economic model is a simplification of an aspect of the real world (Stokey and Zeckhauser, 1978); the act of simplifying results in many limitations stemming from reducing a complex system into one that has only a few key inputs. The Alberta Diabetes Projection Model is based on the following assumptions and methodologies 1) methodology to identify a diabetes case, 2) Alberta population projections, 3) increasing diabetes incidence, 4) decreasing mortality, 5) 10 year duration of change for incidence and mortality, and 6) 1996 Saskatchewan health care costs adjusted to 2005 Canadian dollar values using the CPI.

An important limitation in the Alberta Diabetes Projection Model is the administrative data used. Case definitions were used to identify people with diabetes; that is, identified people had to either be diagnosed by a physician or admitted to a hospital (Johnson and Vermeulen, 2007). The case definition of an individual with diabetes may result in a possible misclassification of diabetes; an individual admitted to a hospital for diabetes symptoms may not yet be diagnosed by a physician and recognized as a diabetes case or an individual diagnosed with diabetes could be missed because of a small number of physician visits (i.e., by not accruing 2 physician claim in 2 years in order to be identified as a diabetes case) (Johnson and Vermeulen, 2007). This could result in biased incidence and prevalence numbers. However, the methodology to identify people with diabetes has been consistently applied each year and the Alberta Diabetes Projection group is confident that the numbers reflect the true epidemiologic trends of diabetes in Alberta (Johnson and Vermeulen, 2007).

Another potential limitation are the Alberta population projections obtained from Alberta Health and Wellness, which are based themselves on demographic trends and assumptions. Mortality, fertility, and migration rates were obtained from two sources: the Alberta Health Care Insurance Plan Stakeholder Registry and Alberta Vital Statistics. Historical data from these two sources were analyzed and used to project the mortality, fertility, and migration rates in Alberta from 2006 to 2035. The factors and trends

observed at the time of the projections are assumed to continue to 2035; but mortality, fertility, and migration rates are influenced by economics and politics, factors that change over time.

Additional assumptions and inputs can also limit the Alberta Diabetes Projection Model. The projection model assumes that incidence and mortality rates will continue to increase at a linear rate for an additional ten years (2006–2015), based on trends seen in the preceding decade (1995–2005) (Johnson and Vermeulen, 2007). The true duration and trend of incidence and mortality rate increases in Alberta are unknown and will be affected by many external factors such as health care technology, economics, and politics. However, the epidemiology of diabetes with respect to increasing incidence rates and decreasing mortality rates observed in ADSS data are also observed in Ontario (Lipscombe and Hux, 2007). A 10-year duration of the trends seen in incidence and mortality is reasonable as these trends correspond to trends seen in obesity rates and unhealthy lifestyles that individuals are experiencing.

The cost data was obtained from the Saskatchewan Health database. In order to update and adapt the 1996 Saskatchewan health care costs to the Alberta Diabetes Projection Model, the costs were inflated 10 years using the National CPI index. This adjustment assumes that the health care management and treatment of diabetes are at same levels as 1996. For example, the cost of drugs, technologies, and human resources to treat diabetes was assumed to be the same in 2005 as it is in 1996. This may lead to an underestimation of health care costs, due to the introduction of new treatments, as well as different, more intensive approaches to diabetes management in the past decade. For example, the Saskatchewan Health costs were estimated from a period prior to the Canadian Diabetes Association 2003 clinical guidelines, which outline the proper and cost effective treatment of diabetes and its related co-morbidities. On the other hand, this standardization of treatment may have reduced the overall health care costs associated with diabetes treatment through improved quality of care and the proper management of diabetes and its related co-morbidities.

Price indexes are used to compare prices of a bundle or class of goods differ between time periods. The Bank of Canada CPI was used to inflate the 1996 costs to 2005 Canadian dollars (Bank of Canada, 2007). The Bank of Canada CPI index is a 'core

CPI' which is a measure of inflation and excludes certain volatile items (fruits, vegetables, gasoline, fuel oil, natural gas, mortgage interest, inter-city transportation and tobacco products (Bank of Canada, 2007). The class of goods the CPI covers can be quite narrow or broad. For example, there could be a CPI used for things bought by a consumer or more specifically steel mill products. Using a different CPI in the projection model would result in a different cost output depending on the bundle of goods the price index was based on. If we use a health bundle of goods, the costs projection in this model would be different; a higher CPI would result in higher estimated costs while a lower CPI will result in lower estimated future costs.

Another limitation is the lack of clinical or patient specific risk behaviors. The Alberta Diabetes Projection Model treats every individual in the model as equal and does not incorporate data on diabetes risk factors (BMI, physical inactivity, diet, smoking, hypertension) (Health Canada, 2002) and the model does not know the risk factors of individuals who develop diabetes. The projection model is also unable to separate out the different prevalence rates among different ethnicities; for example, aboriginals have been found to have higher prevalence rates than the normal population (Hemmelgarn et al., 2007), however aboriginals are assumed to be part of the full population included in this model. Finally, the projection model, in its current form, does not break down prevalence rates and costs by health region in Alberta, which may be useful for policy makers to direct population level interventions.

5.5 Sensitivity Analyses

Eight various sensitivity analyses were performed using the Alberta Diabetes Projection Model and forecasts that diabetes prevalence may reach a maximum of 35% and 42% in females and males, respectively, with total costs reaching a maximum of over 1.2 billion dollars and over 1.3 billion dollars in females and males, respectively; this assumes that incidence and mortality trends, seen from the ADSS data, will continue for another 15 years.

From Scenario 1, which assumed that incidence and mortality rates will remain at constant 2005 levels, results in the lowest prevalence growth see in the sensitivity analyses. However, overall diabetes prevalence rates are still increasing and will reach a

maximum of 20% in the 70-74, 75-79 and 80-84 age bands from a minimum diabetes prevalence rate of 15% in the 75-79 age band in 2005. This increase is likely due to the changing population demographics which is shifting from younger age groups (less than 50 years of age) to older age groups (50+ (Figure 4.2), combined with high incidence rates in the older age bands (50+).

Comparing scenario 5 and scenario 8, the model is able to isolate the effects of declining mortality rates for a duration of 15 years on overall prevalence and costs of diabetes. The projection models predicts that declining mortality rates results in a increasing prevalence rate resulting from the increasing number of diabetic individuals remaining in the population (Table 4.19; Table 4.22). The declining mortality rates also have a substantial effect on total health care costs increasing costs by 53 and 71 million in females and males, respectively (Table 4.18; Table 4.21).

Comparing scenario 5 with scenario 7, the model is able to isolate the effects of increasing incidence rates for a duration of 15 years on the overall prevalence and costs of diabetes. The projection models predicts that increasing incidence rates will result in a substantial increase in the number of people with diabetes (Table 4.19; Table 4.22) resulting in total health care costs increasing by 214 and 241 million dollars by 2035, in females and males respectively (Table 4.18; Table 4.21).

From Scenarios 2 and 3, varying the rate of increase in incidence rates does not have that large of an effect on prevalence rates and costs compared to the duration of incidence and mortality change (Scenario 5 and 6), which results in more people with diabetes and higher health care costs. Policy efforts should be targeted at curbing the upward trend of diabetes incidence through primary prevention programs.

5.6 Strengths of the Alberta Diabetes Projection Model

The Alberta Diabetes Projection Model is stronger than many of the previous models reviewed in this study for several reasons: 1) the model adopts a population wide perspective, 2) the Alberta model incorporates the most recent and relevant inputs (incidence and mortality rates, Alberta population projection), and 3) the model variables may be manipulated for sensitivity analyses. The Alberta Diabetes Projection Model is an improvement on previous models (Wild et al., 2004; King et al., 1998; Boyle et al.,

2001; Narayan et al., 2006; Honeycutt et al., 2003) because it uses administrative data sets from the whole population, incorporating the most recent incidence, mortality rates, and population projections. By avoiding the complications of incorporating numerous diabetes risk factors, the Alberta Diabetes Projection Model has an advantage over the clinical based projection models created by Clarke et al., (2004), O'Reilley et al., (2006), and Palmer et al., (2004). The ADPM contains information applicable to the general population and provides a good estimate of the future burden of diabetes in Alberta. The Alberta Diabetes Projection Model is a powerful tool for policy makers. The model takes a population wide perspective and inputs can be manipulated to see their effects on population levels. For example, if a policy maker wishes to see the effects of a new technology that will decrease mortality rates among people with diabetes by 3%, the ADPM can project the effects of that specific technology on prevalence rates and costs in Alberta. The power of the ADPM resides in its ability to project intervention effects on the population as a whole, not just one specific population. This perspective of a population level intervention strategy is consistent with Geoffrey Rose's (2008) population strategy. Rose believes "preventive medicine must embrace both high risk approach and population approach, but of the two, the power resides with the population strategy."

5.7 Conclusions

The Alberta Diabetes Projection Model is a life table model that incorporates population based epidemiological data with local population projections and provides a strong prediction of the future burden of diabetes in Alberta. It can be used to inform policy makers on the importance and urgency of the diabetes epidemic in Alberta. The Alberta Diabetes Projection Model is based on the most recent epidemiological data (1995–2005) and will continually be updated with the most recent data from the ADSS, providing an accurate and up to date projection of the diabetes burden in Alberta.

Other diabetes prediction models discussed in this thesis are Wild et al., (2004), King et al., (1998), Boyle et al., (2001), Narayan et al., (2006), and Honeycutt et al., (2003). The Alberta Diabetes Projection Model is more relevant to local population-wide policies than the UKPDS Model (Clarke et al., 2004), ODEM (O'Reilly et al., 2006) and

the CORE Diabetes Model (Palmer et al., 2004), which are based on clinical trial data and may not incorporate risk factors inherent in the population.

The Alberta Diabetes Projection Model is a relevant and powerful tool for policy makers; the model is simple and easily understandable for several reasons: 1) the model adopts a population wide perspective utilizing Alberta epidemiologic data 2) the model only incorporates the most recent and important inputs to project the future burden of diabetes and costs in Alberta – diabetes incidence and mortality 3) the model inputs may be manipulated (incidence and mortality rates, and costs) to model out different scenarios. From the Alberta Diabetes Projection Model, effective policies to slow and delay the growth of diabetes in Alberta will free up important resources for other important goods and services. In the future, the model can be applied to other provinces and cost analyses can be performed with population level interventions to assess their impacts on health care costs.

Improvements to the Alberta Diabetes Projection Model would be 1) to update the current model with current epidemiological data from Alberta Health and Wellness 2) to decrease the amount of error between the predicted and actual trends in incidence and mortality, through different statistical analysis 3) to update the costs with the most recent Alberta health care costs and 4) to modify the aging in the model – instead of aging a equal proportion of the age band into the next age group, the model should age the oldest age band into the oldest age group. Currently, in the 10-14 age band, the model ages one fifth of the age group into the 15-19 age band. Future improvements of the model will age only the 14 years olds from the 10-14 age band into the next age band; this will be done for all age bands for all years.

The population based approach of this model and simplicity and the ease of manipulation of the various input variables (incidence rates and mortality) make this model ideal for future cost effectiveness analysis on a population level.

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Appendix A: Age bands, population projections, formulas

Age bands (for females and males)

1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85+

Formulas

$$\%\ Difference = \frac{(Predicted - Actual)}{Actual} \times 100\%$$

$$\%\ Change = \frac{(New\ value - Base\ value)}{Base\ value} \times 100\%$$